STUDIES ON PELAGIC SHRIMPS IN THE DEEP SCATTERING LAYER OF THE WEST COAST OF INDIA

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in

MARINE BIOLOGY

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2001

DEDICATED TO

MY BELOVED PARENTS

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CERTIFICATE

This is to certify that the thesis entitled "STUDIES ON PELAGIC SHRIMPS IN THE DEEP SCATTERING LAYER OF THE WEST COAST OF INDIA" submitted by Mr. P.K.KARUPPASAMY for the award of Degree of Doctor of Philosophy in Marine Biology of Karnatak University is based on the results of experiments carried out by him under my supervision. The thesis or a part thereof has not been previously presented for any Diploma or Degree.

(KUSUMA NEELAKANTAN)

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P.K. KARUPPASAMY

CONTENTS

CHAPTER 1

GENERAL INTRODUCTION

CHAPTER 1

1. 1 GENERAL INTRODUCTION

Today, when so much is being said and written about our interests in the ocean, it is particularly important to retain our perspective. Of course, the present pattern is likely to change, although how rapidly or dramatically we do not know. What is certain is that we shall use the ocean more intensively and in a greater variety of ways. Our greatest need is to use it wisely. The general goal of ecological research to which marine biology makes an important contribution, is to achieve an understanding and to turn to our advantage all the biological processes that give our planet its special character. Marine biology is focussed on the problems of biological production, which are closely related to problems of production in the economic sense as well. Our most compelling interest is often narrower. It lies in ocean life as a renewable resource, primarily of protein-rich foods and food supplements for our domestic animals and to us and of secondary materials and drugs. At this point, it is time to inquire about the future expectations from the ocean which is or three dimensional environments provides protein rich seafoods alternate to agricultural products from land. Other than this, nonliving resources such as minerals, oil, medicinal properties of the various marine organisms etc. are resources we collect from the sea.

The present harvest of marine living resources from the world oceans is about 87 million tonnes in 1996 (Anon., 1998). More than 90% of this harvest is finfishes; the rest consists of whales, crustaceans, molluscs and other invertebrates. It is now a common knowledge that fish is one of the few major foodstuffs showing an increase in global production that continues to exceed the growth rate of the human population. This increase has been accompanied by changing patterns of use. Although some products of high unit values that includes luxury foods, such as shellfish, have maintained or even enhanced their relative economic importance and the trend is that moderate catch is used directly for human consumption and the bulk is reduced to fishmeal for animal feed and manure. There are also large aggregations of pelagic animals that live further down and are associated particularly with the "Deep Scattering Layer" (DSL), the sound-reflecting stratum observed in all oceans, which has vast potential to provide exploitable resources.

Early during World War II, when the use of echo sounders was being experimented in the oceans as a means of detecting submarines and the bottom, these devices (now known as sonar) regularly began to pick up echoes. They came, not from the bottom, but from the sources in the water column itself, hundreds or even thousands of metres above the known bottom. Such echoes are called "false bottom", which exists within the sea and strongly reflects sound pulses. Because of the impact these layers have on echo sounding records these are aptly referred as Deep Scattering Layers (DSL) (Nybakkan, 1988).

Deep Scattering Layer is a widespread stratum of the oceans, which causes scatter or reflects pulses from the echosounding equipment. Marine organisms, which from the DSL absorb, diffuse and reflect, and produce sound. Deep waters (Deeper than 650 ft) generally has one or more well-defined layers. These Deep Scattering Layers are easily detected by an echosounders operating in 3-60 kHz frequency range. Many DSL organisms perform daily vertical migrations and these movements were confirmed by various acoustic studies. These reflections, which appeared as "false bottom" are collectively known as the **"Deep Scattering Layer"**. These scattering layers migrates towards the surface at dusk and descends from the surface at dawn and these movements are mainly attributed to the negatively phototropic nature of the organisms of the DSL migrations and also as a collective means for escaping from predator. The DSL is a layer of living organisms, ranging from almost microscopic zooplanktons like copepods to macroorganisms like shrimps and squids that prey from within and outside the DSL. This layer migrates vertically in the water column, dependent on light intensity and occurs at depths between 230 and 800 m during day (although most concentrates at 310 to 460 m) and close to the surface at night (Bhatt, 1978., Ingmanson *et al.*,1973).

During day, they may appear as two or three layers varying in depth from 200 to 700 metres. At night, these different layers migrate towards the surface, where they are often merged into a single broad band. At dawn the layers are found at deeper depths. Although, first this phenomenon was interpreted as some physical discontinuity of the water, the DSLs are now understood to be concentrations of mid-water animals, and the movement of the layers towards the surface at night is the result of vertical migrations similar to that undertaken by pelagic zooplankton. Presumably, these mid-water animals are migrating to the surface at night in order to feed on the abundant plankton (Nybakkan, 1988).

Deep Scattering Layers have been found in all oceans. They are best noticed in areas with high surface productivity and are faint in areas of low productivity. The world's expanding population cannot look to the deep-scattering layers as a direct source for food. Nevertheless, the organisms of the DSLs are well up in the pyramid that requires pounds of diatom fodder to support the growth of a pound of commercial fish. The DSLs play a major role in the biological economy of the seas (Dietz, 1942). The animals of the DSLs seem to constitute an important source of food for commercially important fishes; surely they are an important link in the food chain of the ocean. Today it's clear that the scattering layer consists of small, nocturnal marine organisms.

There are also reports of non-migratory scattering layers in the upper 100 m that are found to occur during day and night. The common belief is that the migratory organisms of the scattering layers hide from predators in the darkness of deep waters during day and swim upwards to feed from the plankton rich surface water at night (Hersey and Backus, 1962). The DSL observed in all oceans of the world is composed of rich and varied bio-composition. These phenomena have aroused scientific interest ever since its discovery in 1942 (Raitt, 1948). Johnson (1948) described diurnal vertical movements of various layers of the DSL and linked them with plankton concentration. A large number of investigations have focussed on the question, as to what extent animals contribute to this phenomenon. Multiple layers were also detected at single localities at midday depth and the intensity and migrational pattern was noted to vary greatly at widely separated points in the oceans. Tucker (1951) noticed a correlation between more intensive deeper scattering and the vertical distribution of fishes and the shallower less intensive scattering and the distribution of euphausiids. Pearcy and Laurs (1966) observed that day catch rates of mesopelagic fishes were larger than the night catch at depths of 150-500 m and the reverse was the condition from the surface to 150 m.

Preliminary investigations on the sound scattering layer/ deep scattering/ bio acoustic layers of the Indian Exclusive Economic Zone (EEZ) opened up new vistas for indepth research on the pattern, distribution, processes and diurnal vertical migration of DSL bio-composition. This layer/layers consist of stratified group of organisms which can 'scatter' or 'reflect' pulses from the echo sounder and are capable of migrating from surface down to about 1000 m and *vice versa* depending on the light penetration into the water column. DSL is a real trophic network that carries numerous food chains. The biotic components of the DSL include macro zooplankton like siphonophores, euphausiids, amphipods, copepods, chaetognaths, medusae, salps, pteropods, ostracods, isopods, doliolids, larval forms like alima, decapod larvae, phyllosoma larvae, etc. and micro nektons such as crabs, cephalopods, leptocephalus, fish juveniles, and mesopelagic fishes belonging to families such as Myctophidae, Photichthyidae, Gonostomatidae, Sternopthychidae, Melanostomiidae, Stomidae, Astronesthidae, Nemichthyidae, etc. These mesopelagic resources especially the pelagic shrimps have assumed importance in recent years in view of their potential for exploitation for human consumption and production of fish meal and as a source of protein.

Kinzer (1969) reported about the organisms occurring in the DSL of the extremely O_2 deficient waters in the Western Arabian Sea during February - March. Acoustic surveys were carried out in the Lakshadweep Sea adjacent to islands and recorded DSL in the oceanic areas at depth of 300-450 m and 750-950 m with characteristic vertical migration (Silas, 1972). He found that the DSL close to the island constituted an important source of forage to pelagic fishes and squids. Though considerable work was done on different aspect of this ecosystem of world oceans, investigations from India on this subject are scanty. Menon (1990) has described the DSL, single or multi-layers appeared in all the geographical areas of the Indian EEZ under investigation in varying intensities and characters. Mathew and Natarajan (1990) studied the role of euphausiids in the DSL biocomposition and continuous monitoring of DSL carried out in the early morning and late evening hours revealed that the DSL oscillated between surface and around 600 m depth. The descend from surface started as discrete layers which detached one by one and went down ultimately to depth more than 400 m. Similarly the upward migration in the evening also took place as definite layers from the main DSL and moved upto surface. Natarajan *et al.* (1996) described the echoscope connected to the echo sounder showed the DSL in different colours depending upon its density. The continuous monitoring on echogram revealed that the DSL was observed at surface during night and at 600 m depth during day.

The crustaceans especially the shrimps belonging to various families have probably been a source of food for human from very early times. The suborder Natantia of decapod crustaceans represents one of the world's most commercially valuable groups of marine species. This group consists of two large sub-groups. **Penaeidean shrimps**: which form the basis of valuable trawl fisheries in many tropical and subtropical countries and **Caridean shrimps**: which are more widely distributed, but less commonly exploited (King and Butler, 1985). Caridean shrimps, an important component of the oceanic micro nekton with their large size and vivid coloration, are among the most distinctive organisms in the Isaacs Kidd - Midwater Trawl (IKMT) catches. In the Pacific Ocean, shrimps form 12-25% of the biomass. This dominance of the pelagic shrimps seems to be widespread in all oceans. According to Omori (1974) the relative abundance of each group changes with latitude and with depth. Seasonal changes in the composition of the assemblages appear to be small, but have received little study. Menon and Prabadevi (1990) reported that decapods formed 12% in the total plankton biomass of the DSL with the bulk appearing in night hauls. Similarly pelagic shrimps had higher abundance at night (69.5%) than in day (50.5%) in the DSL of the Indian Ocean.

Omori (1974) stated that a total of about two thousand species of prawns have been recorded from the world oceans and as many as 210 species spent their complete life in the pelagic realm. Though the occurrence of pelagic shrimps in the mid and deep waters of the ocean has been reported as early as the middle nineteenth century, serious attention to study their role in the productivity of the sea has been paid only in recent years. In Indian waters, the earliest attempt to throw light on the taxonomy of pelagic shrimps was the faunstic work of Alcock (1901) who listed several species along with benthic forms from the collection of the marine survey ship " Investigator". Later Kemp (1917, 1925); Nataraj (1942, 1947); George and Rao (1966); Rao (1968); and Suseelan (1984) have recorded many more species from the west and east coasts of India and studied their taxonomy.

The knowledge was restricted to mere records on the occurrence of the species and their systematics. There was no study regarding the possible commercial concentration of pelagic shrimps in our waters. Since little attention has hitherto been paid to the study of pelagic shrimps, this account has been presented mainly to indicate that any broad based research programme on pelagic shrimp ecosystem is possible.

The present study is also aimed to understand the pelagic shrimps of DSL, whether it can form an exploitable resource of its own or it remains only as a source of food for commercially exploited epipelagic and mesopelagic organisms. Knowledge of the distribution and biology of the pelagic shrimp population would be of great relevance in the management of this resource. Biomass estimation of pelagic shrimps is necessary for a proper understanding of the role of the groups in the economy of the sea. Lack of such information from Indian waters has prompted to carryout a detailed investigations on the pelagic shrimps based on the collection of " **Fisheries Oceanographic Research Vessel (FORV)** ***Sagar Sampada*** " (Figure 1) with the following objectives.

Fig. 1 Research vessel FORV *Sagar Sampada*

Objectives

1. Identification of the various species of the pelagic shrimp families present in the DSL of the Indian EEZ.

2. To evaluate the distributional patterns (geographic, bathymetric and seasonal) of pelagic shrimps in the EEZ.

3. Biomass estimations (nos./$1000m^3$ and tonnes/1° squares) and identification of the areas of potential resource.

4. To analysis and evaluate the feeding ecology and length-weight relationship of selected species (*Oplophorus typus*).

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CHAPTER 2

TAXONOMY

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2. 1 INTRODUCTION

The systematic studies of pelagic shrimps advanced considerably since the various oceanographic research expeditions under taken by the European countries and United States during the late nineteenth to mid - twentieth centuries. However, many species within the genera have not been thoroughly described yet. There are still some confusion in the taxonomy and the number of species present in many genera of pelagic shrimps and proper keys to species level identification are lacking. The important contributions to the taxonomy of penaeids (Family Penaeidae) and *Sergestes* (Sergestidae) were made by Bate (1888), Kemp (1909, 1910 a & b, 1922), Hansen (1919), Sund (1920), Burkenroad (1936, 1937, 1940, 1981), Barnard (1950), Yaldwyn (1957), Perez Farfante (1969, 1977, 1980a, 1985), Kensley (1971 a & b) and Perez Farfante and Kensley (1997). Those by Kemp (1920, 1939), Stephensen (1923), Balss (1925), Chace (1936, 1940, 1947) and Holthuis (1955) are essential for the identification of the carids (Section Caridea).

Taxonomic studies of deep-sea prawns inhabiting the deeper waters beyond the littoral zones began with the collections of the great oceanic expedition from about the middle of the 19^{th} century. The results of these, which were published from time to time and those of several local investigations carried out thereafter from different parts of the world has essentially contributed to our knowledge on this group.

There is no consistency in the usage of the term, "prawns" and "shrimps" to denote any particular group of Natantia (Holthuis, 1980). In the present work, these terms are used analogously.

Our knowledge on the deep-sea prawns of the Indian Ocean region is primarily based on the collections of the Indian Marine Survey steamer INVESTIGATOR (1884 - 1925) and VALDIVIA EXPEDITION (1898 - 1899), the Cape government trawler S.S.PIETER FAVRE (1898 - 1907) and JOHN MURRAY EXPEDITION (1933 - 1934) and from the reports of various authors since the close of last century. Stebbing (1914) and Barnard (1950) from South African waters (S.S. PIETER FAURE) and the expedition reports of Balls (1925, VALDIVIA), Ramadan (1938), Calman (1939) and Tirmizi (1960) (JOHN MURRAY) provide information on the occurrence and distribution of several species along the Western Indian Ocean and some areas of the coast traversed by VALDIVIA. The earliest studies from the Indian waters were those of Wood-Mason (1891), Alcock (1899, 1901, 1906), Alcock and Anderson (1899) and Kemp and Sewell (1912) who worked extensively on the collections of the INVESTIGATOR from the Arabian Sea, Bay of Bengal and Andaman Sea. Later, John and Kurian (1959), Kurian (1964), George (1966), George and Rao (1966), Suseelan and Mohamad (1968), Silas (1969), Mohamad and Suseelan (1973) and Suseelan (1984) reported the occurrence of a few species along the south west coast of India and the studies were based on the deep-water trawling surveys of the research vessels CONCH, KALAVA, VARUNA and other larger trawlers.

GENERAL REMARKS

Shrimps and prawns are grouped under suborder Natantia of the Crustancean Order Decapoda. They are large group of crustaceans with an extended abdomen (or "tail "), varying in size from microscopic to about 35 cm body length (measured dorsally from the posterior orbital margin to the end of the tail, excluding the rostrum and the appendages). Taxonomically, shrimps and prawns belong to the " swimming groups ". Their body, as defined by Calman (1909), is almost always laterally compressed, rostrum usually compressed and serrated, first abdominal somites not much smaller than the rest, antennules generally with stylocerite; antennal scale generally large and lameller; legs usually slender; except sometimes a stout chelate limb (or) pair, which may be any one of the first three rarely coalesced and with only one fixed point in the carpopropodal articulation (with some doubtful exception); some times with exopodite, podobranchiae.

hardly ever present on the first three and never on the last two pairs; pleopods always present in full number, well developed, used for swimming. According to Chan (1998) the large assemblage of species, 3,047 species of shrimps and prawns known to date, subdivided into four major groups, namely Sergestoidea (about 94 species), Penaeoidea (about 376 species), Stenopodidea (about 60 species) and Caridea (about 2517 species). Although the Caridea comprises the majority of species; only some are abundant enough to be of interest to fisheries. Most of the commercial shrimps and prawns belong to the Penaeoidea. At present, around 300 species of shrimps and prawns are of economic interest worldwide and out of these; only about 100 comprise the principal share of the annual world catch.

REMARKS

The terms "shrimps" and "prawn" have no definite reference to any known taxonomic groups. Although the term "shrimps" is sometimes applied to smaller species, while "prawn" is more often used for larger forms, there is no clear distinction between both terms and their usage is often confused or even reverse in different countries or regions. Therefore, no attempt has been made here to restrict or define their meaning (Chan., 1998).

In this chapter, heading for each family or species is followed by a reference to the original publication of the family or species name. In case of categories higher than families (Infra order, Super families) the heading is followed by a citation of the author who first defined the limits of the group as now accepted and their names and authors given in the synonyms, are not necessarily listed in the bibliography.

2. 2 MATERIALS AND METHODS

The Pelagic shrimp collections were carried out by Isaacs-Kidd Mid-water Trawl (IKMT) during May 1998 to December 2000 on board FORV *SAGAR SAMPADA* in the area between 6°- 21°N and 66°- 77°E. The gear IKMT is made up of a conical net attached to a wide 'V' shaped diving Vane (Isaacs- Kidd, 1953). At each end of the diving Vane and from a spreader bar at the top foremost part of the net comes the bridle, arranged so that the net takes up a catching position during towing. The net has 2.5 m total length and 4 m vertical opening with a mesh size of 1.5 mm (stretched) at the cod-end. The net is operated for 30 minutes obliquely along the DSL at a towing speed of 3-knots/hour (Figure 2).

The samples were collected from DSL, after ascertaining the depth of their occurrence from the acoustic recordings from the echo sounder. The echo sounder with frequency of 38 kHz and 120 kHz was used for obtaining continuous traces of echoes from different depth zones at different times of day and night or continuously. These Deep Scattering Layers appear either as single or multiplelayer and the thickness of the layer varied between day and night. The DSL thickness is referred as the distance between (in metres) the upper strata and lower strata of the DSL in the water column between actual surface and sea bottom (Figure 3).

Usually the samples are taken from principal layers. In case of multiple layers, samples are taken separately from each layer to study the stratification of the DSL biocomposition. The layers were sampled at different bathymetric positions in day and night time in order to study the characteristics and behavior of ascends and descends of various groups of plankton and micronekton. Stations covered during May 1998-December 2000 period within an area bounded by latitude 06° to 21° N and longitude 66° to 77° E. Samplings were carried out both during day and night (Figure 4).

The identification of pelagic shrimp was done using the key and description of species by Alcock, (1901), Hansen (1919), Kemp (1920), Holthius (1955),

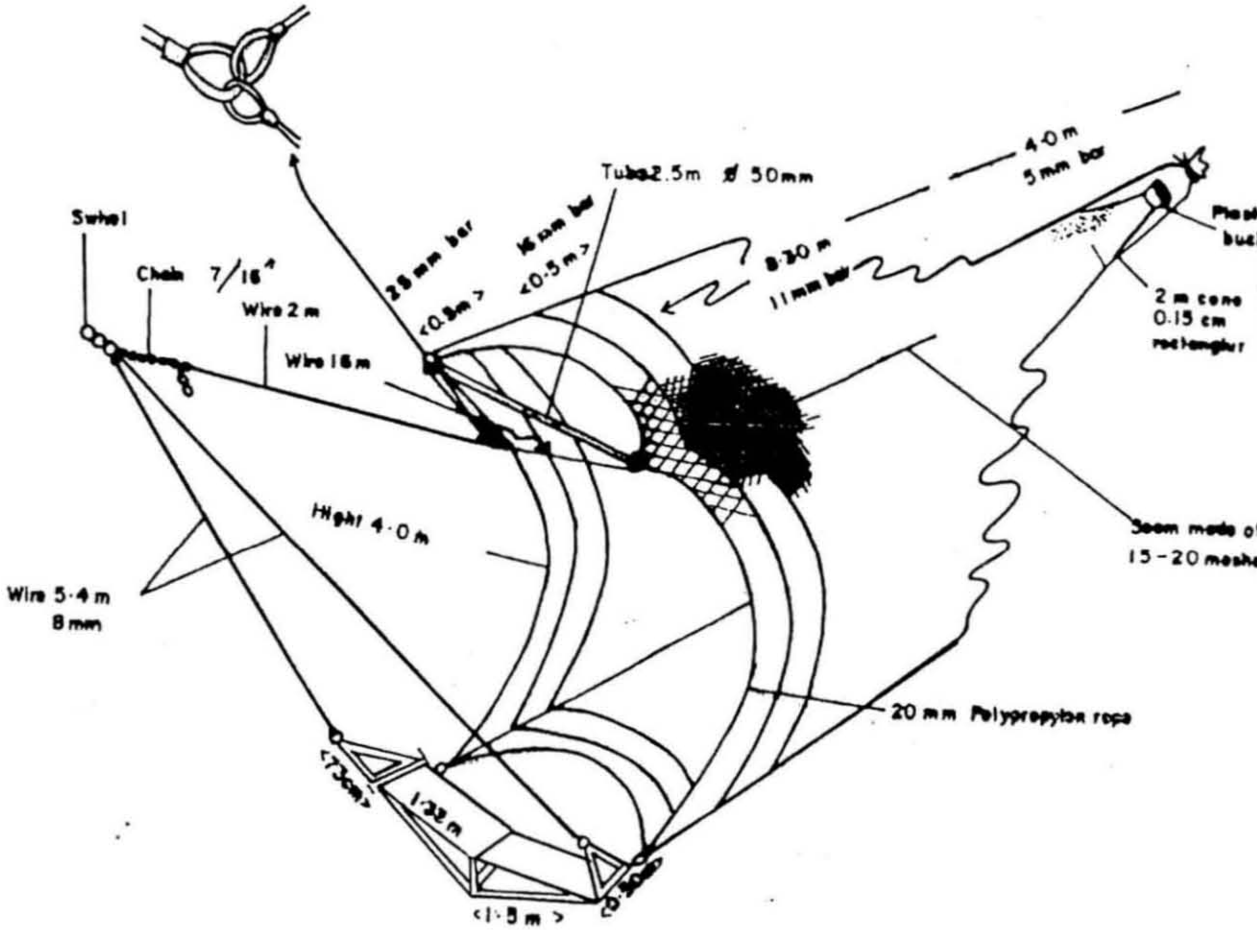

Figure 2. Rigging of the Isaacs-Kidd Midd-water Trawl (IKMT) Depressor made of 5mm Alumminium, total length 2.5 m, weight 25Kg.

Source: N.G.Menon, 2000. Marine Fisheries Research and Management, p.650.

Figure 3. The daily migration of Deep Scattering Layer.

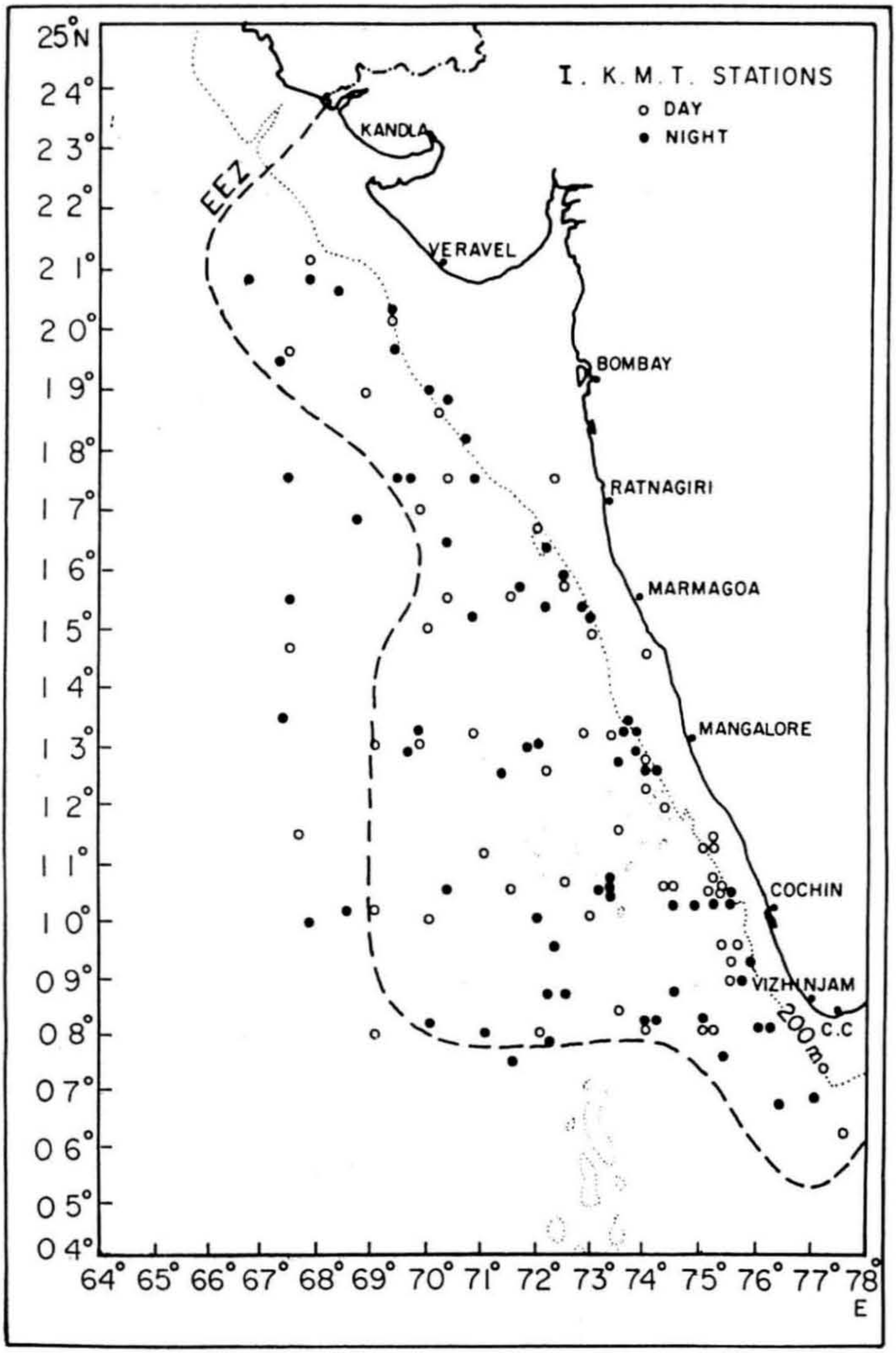

Figure 4. Map showing night and day stations for IKMT collections by FORV *Sagar Sampada*

Yaldywen (1957), George and Rao (1966), Kensley (1971 a & b), Judukin (1978), Burkenroad (1981), Suseelan (1984) and Perez Farfante and Kensley, (1997). The pelagic shrimps of the IKMT collections belonged to 11 families, 19 genera and 29 species, which come under the Infraorders Penaeidea, Caridea and Stenopodidea. These are mostly the unexploited marine species of the Indian coast, as well as a major link in the food chain of the oceans.

REMARKS

As there is no closing mechanism for the IKMT used in our samplings. some contamination of the catches might have occurred with the passage of the net through the water column above layer on setting and hauling. But the amount of contamination might probably be negligible considering the length of time the net would spent in the upper column. While the setting and hauling time is short when compared to the towing time at the desired sampling depth. Another frequently raised criticism is that many important sound scatters are fast swimmers and so escape the net.

2. 3 RESULTS

2. 3. 1 FAMILIES, GENERA AND SPECIES OF THE PELAGIC SHRIMPS IN THE DSL

The result shows that the pelagic shrimps collected from the FORV *Sagar Sampada* IKMT consist of 29 species belonging to 19 genera comprising of 11 families. The following Table gives the details of family-wise species.

INFRA ORDER : PENAEIDEA SUPER FAMILY : PENAEOIDEA		
FAMILY	**GENUS**	**SPECIES**
PENAEIDAE	***1. Pelagopenaeus***	***1. P. balboae***
	2. Funchalia	***2. F. danae***
BENTHESICYMIDAE	***3. Gennadas***	***3. G. praecos*** ***4. G. sordidus*** ***5. G. scutatus*** ***6. G. parvus***
SOLENOCERIDAE	***4. Hymenopenaeus***	***7. H. aequalis***
	5. Solenocera	***8. S. hextii***

<table>
<tr><td colspan="3">SUPER FAMILY : SERGESTOIDEA</td></tr>
<tr><td rowspan="3">SERGESTIDAE</td><td>6. Sergestes</td><td>9. S. seminudus
10. S. semissis
11. S. orientalis</td></tr>
<tr><td>7. Sergia</td><td>12. S. inous</td></tr>
<tr><td>8. Acetes</td><td>13. A. japonicus</td></tr>
<tr><td>LUCIFERIDAE</td><td>9. Lucifer</td><td>14. L. typus
15. L. penicillifer
16. L. hanseni
17. L. orientalis</td></tr>
<tr><td colspan="3">INFRA ORDER : CARIDEA</td></tr>
<tr><td colspan="3">SUPER FAMILY : OPLOPHORIDEA</td></tr>
<tr><td rowspan="4">OPLOPHORIDAE</td><td>10. Oplophorus</td><td>18. O. typus</td></tr>
<tr><td>11. Acanthephyra</td><td>19. A. sanguinea</td></tr>
<tr><td>12. Meningodora</td><td>20. Meningodora sp</td></tr>
<tr><td>13. Notostomus</td><td>21. Notostomus sp</td></tr>
</table>

SUPER FAMILY : NEMATOCARCINOIDEA		
NEMATOCARCINIDAE	**14. *Nematocarcinus***	**22. *N. tenuirostris***
SUPER FAMILY : PASIPHAEOIDEA		
PASIPHAEIDAE	**15. *Leptochela***	**23. *L. (Leptochela) aculeocaudata*** **24. *L. (Leptochela) robusta***
	16. *Psathyrocaris*	**25. *Psathyrocaris* sp**
SUPER FAMILY : PANDALOIDEA		
PANDALIDAE	**17. *Plesionika***	**26. *P. martia*** **27. *P. alcocki***
THALASSOCARIDIDAE	**18. *Thalassocaris***	**28. *T. carinata***
INFRA ORDER : STENOPODIDEA		
STENOPODIDAE	**19. *Stenopus***	**29. *Stenopus* sp**

2. 3. 2 DESCRIPTION AND DISTRIBUTION

SUPER FAMILY : **PENAEOIDEA** Rafinesque - Schmaltz, 1815

Family : **PENAEIDAE** Rafinesque - Schmaltz, 1815

FEATURES OF THE FAMILY

Body compressed, comparatively slender. Well-developed rostrum, extending to (or) beyond distal margin of eye; armed with dorsal and sometimes also with ventral teeth. Carapace lacking postorbital spine; presence of antennal and hepatic spines; cervical sulcus ending well beyond ventral to dorsal midline. Posterior abdominal somites carinate. Telson sharply pointed, with or without lateral spines. Eye with optic calathus almost always without mesial tubercle, basal article of eyestalk produced into moderately to slightly developed never freely projecting; distomesial scale; ocular plate having no styliform projection. Foliaceous prosartema on antennule, flagella of about same length, borne on apex on third segment. Third through fifth pleopods biramous. Podobranchia on second maxilliped only. Epipods borne on first maxilliped and usually on second, absent on fourth and fifth pereopods. Petasma semi-open (or) semi closed. Second pleopods of males bearing appendix masculina only, lack appendix interna and distolateral projection. Thelycum open or closed

Genus : ***Pelagopenaeus*** Perez Farfante and Kensley, 1997

GENERIC CHARACTERS

Rostrum armed with dorsal and ventral teeth. Carapace with dorsolateral carina. Short (not crossing) incisor processes on mandible. Petasma symmetrical, both halves of same length.

1. ***Pelagopenaeus balboae*** (Faxon, 1893)

Figure 5

Penaeus balboae Faxon, 1893, 24 (7): 211

Funchalia (Pelagopenaeus) balboae (Faxon): Ramadan, 1938 p.64, fig.10a-b, 11a-g

Pelagopenaeus balboae (Faxon): Perez Farfante & Kensley, 1997 P. 124,
Fig.75, 76a-b

MATERIALS EXAMINED

Specimen : Two male adult specimens

Locality : Lat. 12°30'N - Long. 73° 03'E and Lat. 12°59'N - Long. 69° 58'E

Depth of operations : 50 and 200 m

Total length : 60 and 70 mm (The measurements of total length the tip of telson to postorbotal margin of carapace).

DESCRIPTION OF SPECIES

Eye black, eyeball bigger and wider than eyestalk. Rostrum short, armed with (12+1) 13 dorsal and 3 ventral teeth. Pterygostomian and small hepatic spine on carapace. Carapace devoid of orbital and antennal spine. Postrostral carina long and well-marked, antennal carina present; hepatic carina long and extends upto and joins with branchiocardiac, branchiostegal carina also long. Fourth to sixth abdominal segments each bearing a single carina, last ending in a spine. Dorsal antennular flagella, much longer than ventral and extends beyond carapace length. Mandibles with incisor processes short and straight, distal article of biarticulate palp small, symmetrical, triangular. Dactyl of third maxilliped elongate and flat. Petasma symmetrical with lateral lobe not produced into free, distally directed projection.

DISTRIBUTION

Arabian Sea; eastern Pacific Ocean, off Gulf of Panama; Isla de Cocos; Caribbean; Bermuda; Equatorial mid-Atlantic; Off Cape Verde Islands; eastern Atlantic Ocean; Ocean off Congo; southeastern Atlantic and northwest Pacific Ocean.

Genus : ***Funchalia*** Johnson, 1867

GENERIC CHARACTERS

Rostrum armed with dorsal teeth only. An asymmetrical petasma. A much longer incisor processes on mandible a much larger mandibular palp. Presence of antennal spine, markedly dimorphic dactyli of third maxillipeds. Unsulcated dorsal carinae on abdominal somites. Uropods much longer than telson and a superior antennular flagellum which is, but little longer than the inferior antennular flagellum.

2. *Funchalia danae* Burkenroad, 1940

Figure 6

Funchalia (*Funchalia*) *danae* Burkenroad, 1940, p.36.

MATERIALS EXAMINED

Specimen	: One male
Locality	: Lat. 17° 30' N - Long. 67°24' E
Depth of operations	: 60 m
Total length	: 60 mm

DESCRIPTION OF SPECIES

Rostrum short compressed, reaching as far as mid length of second antennular segment. Rostrum with 12+1 teeth dorsally, unarmed ventrally, its lateral ridge well defined. Carapace with antennal, pterygostomian spines and hepatic spines. Antennal, pterygostomian and branchiocardia carina present. Fourth, fifth and sixth abdominal somites bearing continuous, prominent cicatrix. Telson with three fixed subapical spines, preceded by much smallar ones. Frontal margin of carapace below antennal projection, only moderately convex, with well defined pterygostomian spine set well above antero inferior angle. Sides of sixth pleonic somite with only the faintest trace of a second longitudinal ridge between midlateral one and ventrolateral margin.

DISTRIBUTION

Arabian Sea; southcentral Indian Ocean; northwest Pacific Ocean; Azores; Off Canary Islands; Saint Helena Island and Congo.

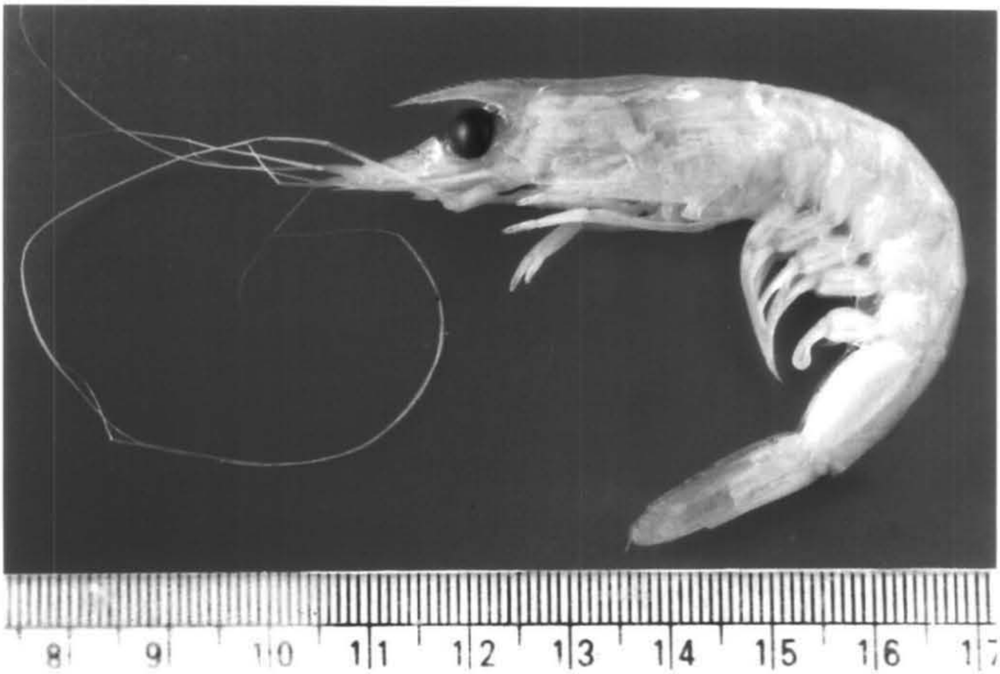

Fig. 5 *Pelagopenaeus balboae* (Faxon, 1893)

Fig. 6 *Funchalia danae* Burkenroad, 1940

Family : **BENTHESICYMIDAE** Wood - Mason, 1891

FEATURES OF THE FAMILY

Integument thin, soft and flexible. Short rostrum, not reaching beyond eyes, laterally compressed, dorsal rostral/post rostral teeth not more than three, usually two or less, ventrally unarmed. Carapace with branchiostegal spine, hepatic spine some times present. Postorbital and postantennal spine absent, cervical and postcervical sulcus reaching middorsal line, branchiocardiac and hepatic sulci usually well defined. Abdominal somites variously carinate, occasionally ending in posterior spine. Telson bearing one to four pairs of lateral movable spines, apex usually truncate, sometimes acute. Eye with optic calathus having mesial tubercle; ocular scale and styliform projection absent. Antennule with prosartema usually represented by tuft of setae; with two elongate filiform flagella. Second pleopod of male with appendix masculina and appendix interna, but no distolateral projection. Third to fifth pleopods biramous. Exopods on first to third maxillipeds present or absent on first to fifth pereopods.

Petasma open, broadly lamellar, with flexible part of ventrolateral lobule attached to dorsolateral for much of, its entire length; ventral costa entirely attached. Thelycum open or sometimes closed; in latter case having shallow seminal receptacles formed by sternal investigations between sternites XII and XIII at base of third pereopods.

Genus: ***Gennadas*** Bate, 1881

GENERIC CHARACTERS

Rostrum short, deep, unidentate. Carapace with infra-antennal angle (if developed) pointing downwards. Carapace with distinct cervical and post cervical sulci reaching dorsal midline, antennal angle narrowly rounded; branchiostegal angle squares, weak hepatic and branchiocardiac carinae present. First to fifth abdominal somites dorsally rounded, sixth somite dorsally carinated. Second and third peduncular joints of first antennae expanded. A vestigial gill on first maxilliped; only sixth abdominal segment dorsally keeled. Telson armed with only one pair of movable lateral spine. Only second maxilliped has podobranchia. Petasma always with "lobus accessories". Appendix masculine on second pleopod bilamellate.

3. *Gennadas praecox* Kemp, 1910

Figure 7 and 7a

Gennadas praecox Kemp, 1910. p.176. fig. 1- 4.

MATERIAL EXAMINED

Specimens	: One male specimen
Locality	: Lat.07° 07'N - Long. 77°12' E
Depth of operations	: 50 m
Total length	: 30 mm

DESCRIPTION OF SPECIES

Rostrum small but elevated above dorsal carina of carapace and bears a small tubercle behind dorsal tooth. Antennary and infra-antennary angles acute, but rather bluntly rounded at apex. The branchiostegal spine minute. Cervical and post-cervical groove of carapace deeply cut; they approach one another very closely along mid-dorsal line, where the distance between them becomes about one-sixth distance from post - cervical groove to hinder margin. Mid dorsal carina runs through out length of carapace, but inconspicuous posteriorly. Antennal scale broad nearly straight, terminates in a small spine, which falls far short of narrow apex of lamellar portion. Carpus of first pair of pereopods and chela almost of same length. Rostral crest does not differ appreciably from that of below said species of same genus. What appears to be its median lobe divided into two halves that are roughly triangular in shape with two long and narrow processes, one on anterior aspect and one, curved and directed inwards.

DISTRIBUTION:

Off Cape Comorin, Lat. 7° 23'N - Long. 75° 44' E only recorded by Kemp, 1910.

4. *Gennadas sordidus* Kemp, 1910

Figure 8 and 8a

Gennadas sordidus Kemp, 1910 . p, 177, pl. XIV, fig 1-3; Tirmizi, 1960, p.349, fig. 40b, 48b, 52-57

MATERIAL EXAMINED

Specimen	: Many specimens
Locality	: Lat.07° 07'N - Lat.10° 31'N and Long. 68° 32 E'- Long.77° 12'E
Depth of operations	: 40 - 350 m
Total length	: 20 - 40 mm

DESCRIPTION OF SPECIES

Accessory lobe present on dorsal surface of petasma and external lobe undivided. Petasma simple and free of folds. It gradually widens towards distal border divided in to three subequal lobes, and median lobe somewhat anteriorly curved spoon-shaped appearance the most distinctive feature of petasma. Branchiostegal spine very small. Distance between cervical and post cervical grooves, less than one-fifth distance from post-cervical grooves to hinder margin of carapace when measured dorsally. Mid-dorsal carina conspicuous behind later groove.

DISTRIBUTION

Arabian Sea; Gulf of Oman; Gulf of Aden; Off Baja California; Gulf of California and southern Mexico; north Atlantic and Indian Oceans.

5. *Gennadas scutatus* Bouvier, 1906

Figure 9 and 9a

Gennadas scutatus Bouvier 1906, p.9, fig. 8, and 13; 1908, p.42, pl.viii; Kemp, 1910, vol. V, p.178, pl.xiii, fig.9, 10; Tirmizi, 1960, p.358, fig. 48, d; & 67 to 69

MATERIAL EXAMINED

Specimen	: Many specimens
Locality	: Lat.07° 59'N - 10° 30' N and Long. 70°26' E - 76°02' E
Depth of operations	: 60 - 200 m
Total length	: 26 - 42 mm

DESCRIPTION OF SPECIES

Second maxilla, anterior lobe of internal lacina, though not wider at apex than at base, widely separated from posterior lobe and narrower than adjacent lobe of external lacina. Third joint of endopod of second maxillipeds wider. Large median distal lobes of truncate petasma and furnished with a sharply pointed process on distal side.

DISTRIBUTION

Southwest Indian Ocean off Natal; Gulf of Aden; Madagascar; Seychelles; Indonesia; east coast of Australia; Indo-Pacific Ocean from east coast of Africa to west coast of America; Off Baja California; Isla Clarion; off Mexico, northeast Atlantic Ocean off Azores; Cape verde Islands; Gabon; Congo; Angola; southeast Atlantic Ocean off Cape of Good Hope and Taiwan waters.

6. ***Gennadas parvus*** Bate, 1881

Figure 10 and 10a

Gennadas parvus Bate, 1881, p.192; 1888, p.340, pl. LIX; Tirmizi, 1960, p.346, Fig. 40a, 48a, 49-51; Perez Farfante and Kensley, 1997, p.65, fig.31

MATERIAL EXAMINED

Specimen	:	One male
Locality	:	Lat. 07° 07'N - Long. 77°12 E'
Depth of operations	:	50 m
Total length	:	40 mm

DESCRIPTION OF SPECIES

Rostrum short, laterally compressed, thin apex pointed crest with one tooth. Sixth somite with a slight indication of a dorsal carina. Antennal scale tapers slightly towards rounded apex, placed more or less in centre of distal margin and reaches far beyond small spine of outer margin. Median lobe of petasma divided into narrow, elongated outer lobule directed upwards and forwards and an internal expanded lobule. Surface of latter curved so as to give it a more or less cup like appearance. Internal lobe nearly as long as external lobule of median lobe with its surface armed with numerous knob-like structures (modified hooks).

DISTRIBUTION

Arabian Sea; southwest Indian Ocean; Japan; Hawaii; northwest Pacific Ocean; northeast Pacific Ocean; south-east Atlantic Ocean of Cape of Good Hope; South Africa and Taiwan waters; Madagascar, Gulf of Aden, Zan zibar and Baja California.

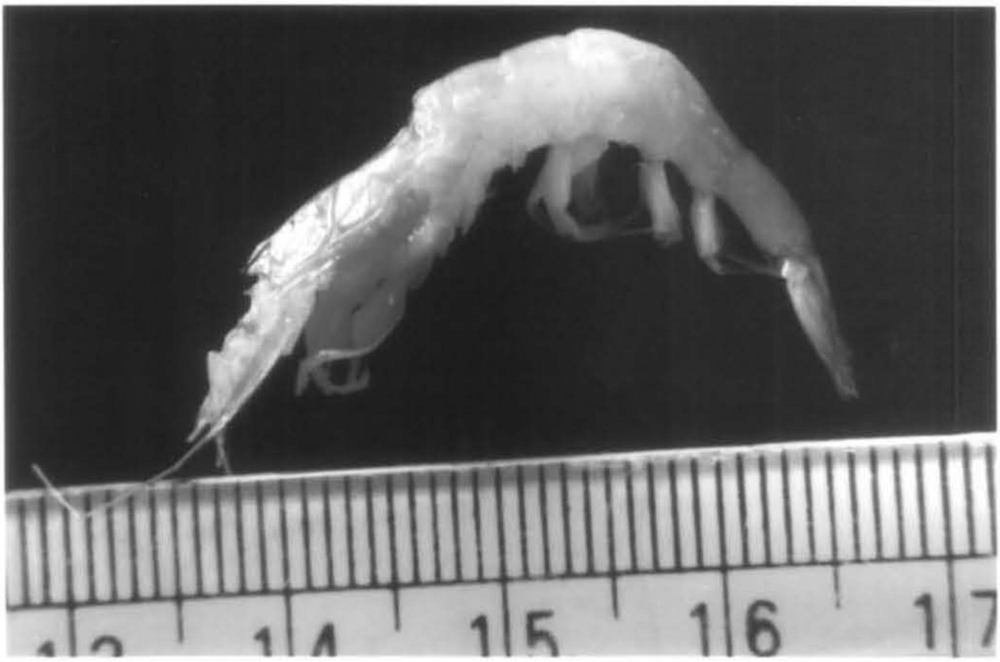

Fig. 7 *Gennadas praecox* Kemp, 1910

Fig. 7a *Gennadas praecox* Kemp, 1910
Male petasma

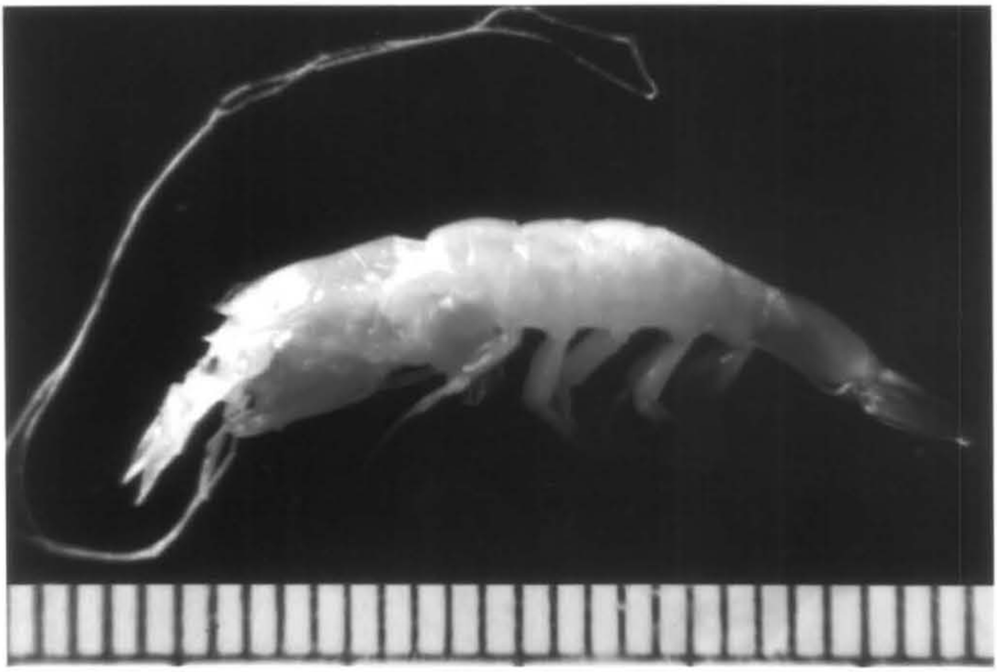

Fig. 8 *Gennadus sordidus* Kemp, 1910

Fig. 8a *Gennadas sordidus* Kemp, 1910
Male petasma

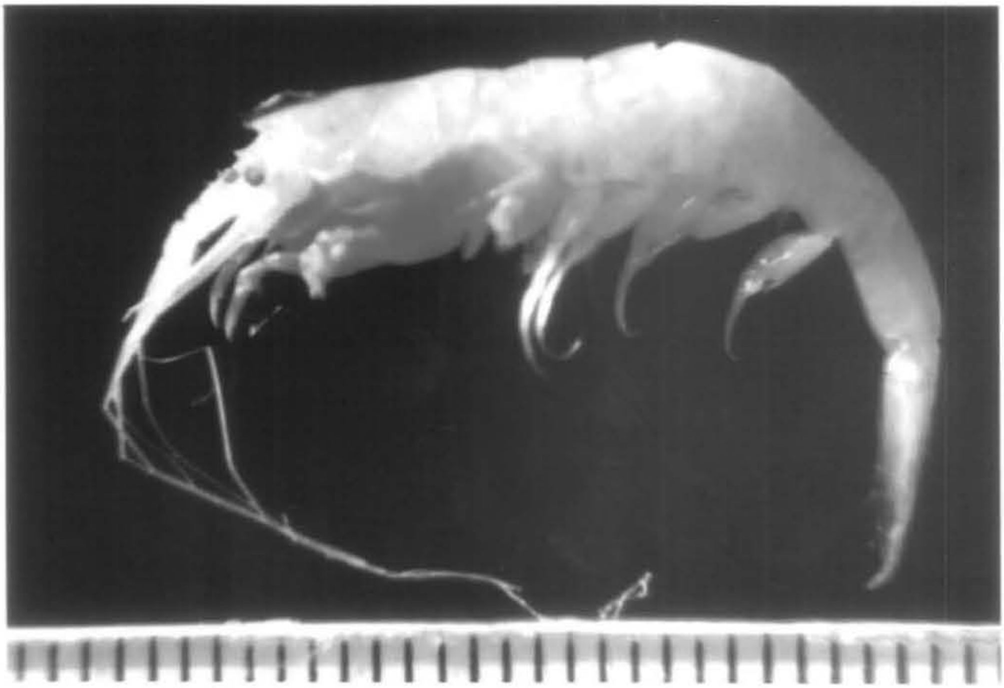

Fig. 9 *Gennadas scutatus* Bouvier, 1906

Fig. 9a *Gennadas scutatus* Bouvier, 1906
Male petasma

Fig.10 *Gennadas parvus* Bate, 1881

Fig.10a *Gennadas parvus* Bate, 1881
Male petasma

Family : **SOLENOCERIDAE** Wood - Mason, 1891

FEATURES OF THE FAMILY

Rostrum laterally compressed, relatively short, armed with dorsal teeth, usually ventral teeth not present. Carapace with postorbital or post antennal and hepatic spines, antennal spines almost always present; orbital branchiostegal and pterygostomian spines present or absent. Cervical sulcus well defined, reaching or almost reaching dorsal midline. Telson apically acute, usually armed with subapical pair of fixed spines occasionally with movable lateral spines rarely without spines.

Eye with optic calathus bearing small mesial tubercle; basal segment of eyestalk produced into strongly / barely developed ocular scale; ocular plate lacking styliform projection. Antennule with prosartema variable in length, uaually long and foliaceous, sometimes reduced to short rigid projection; flagella usually very long. Slender, sub cylindrical or flattened. Exopods on all maxillipeds and pereopods. Third to fifth pleopods biramous. Pleurobranchia may be seen IX to XIV; one or two well-developed orthrobranchia on VIII to XIII; podobranchia on second maxilliped, rarely on other appendages, but never on fourth and fifth pereopods. Petasma open or semi open. Second pleopod of male having appendix masculine; appendix interna, and with basis produced into distolateral, ventrally inclined projection or spur. Thelycum open.

Genus : ***Hymenopenaeus*** Smith, 1882

GENERIC CHARACTERS

Integument thin and flexible. Epigastric and first rostral teeth widely separated from remaining rostral teeth. Post hepatic carina present. Fourth and fifth pereopods flagelliform, very long. Pterygostomian spine absent. Supra hepatic spine absent (Perez Farfante, 1977).

7. ***Hymenopenaeus aequalis*** (Bate, 1888)

Figure 11

Haliporus aequalis Bate, 1888. p. 285 to 286; Alcock, 1901, p.23;

Hymenopenaeus aequalis (Bate, 1888): Perez Farfante, 1977; George, 1979, p.22. fig .1a

MATERIAL EXAMINED

Specimen	: Two specimens
Locality	: Lat. 13°09'N - Long 73°40'E
Depth of operations	: 370 m
Total length	: Male 25 mm & female 40 mm

DESCRIPTION OF SPECIES

Rostrum straight, moderately ascending, not reaching to end of 2nd joint of antennular peduncle. Rostrum armed dorsally with 8 teeth, two of them, on gastric carina remote from others. Fourth, 5th and 6th abdominal terga sharply carinated. Both hepatic and antennal regions furnished with 4 teeth. Eye large, their maximum diameter at least twice that of stalk. Last two pairs of legs long and flagelliform.

DISTRIBUTION

Arabian Sea; Sri Lanka; Andaman Island; Indonesia; south China Sea; Philippines; Taiwan; Japan; Wallis Futuna Islands; Hawaii and east coast of Africa.

Genus : ***Solenocera*** Lucas, 1849

GENERIC CHARACTERS

Rostrum short, carapace with cervical groove extending dorsally interrupted only at mid-dorsal line. Postorbital spine present. Dorsal ventral antennular flagella flattened ventral pair forming trough, four together constituting respiratory tube. A small tubercle on eyestalk. Exopods on all maxillipeds and legs. Epipods on maxillipeds second and third and all legs. Telson trifid, without movable spines. Appendix masculina on pleopod 2 male bilamellate. Petasma with dorsolateral lobule bearing terminal process lateral ramus of uropod lacking distolateral spine.

8. *Solenocera hextii* Wood-Mason, 1891

Figure 12

Solenocera hextii Wood-Mason, 1891, p.188 and Oct.1891, p.275; Alcock, 1901, p.20; Muthu, 1971, p.154; George 1979, p. 24;

MATERIAL EXAMINED

Specimen	: One male specimen
Locality	: Lat. 16° 30'N - Long. 72°14'E
Depth of operations	: 205 m
Total length	: 40 mm

DESCRIPTION OF SPECIES

Rostrum ascendant and armed with seven dorsal teeth, produced as an extremely well marked carina almost to posterior border of carapace. Tip of rostrum reaches end of basal joint of antennular peduncle. A very deep-cut L-shaped groove with posterior limb parallel with post rostral carina on either branchiostegal region. Postorbital, antennal, hepatic spine present in carapace.

DISTRIBUTION

Gulf of Aden; Arabian Sea and Bay of Bengal.

Remarks : This specimen is at its juvenile stage only with pure whitish.

Fig.11 *Hymenopenaeus aequalis* (Bate, 1888)

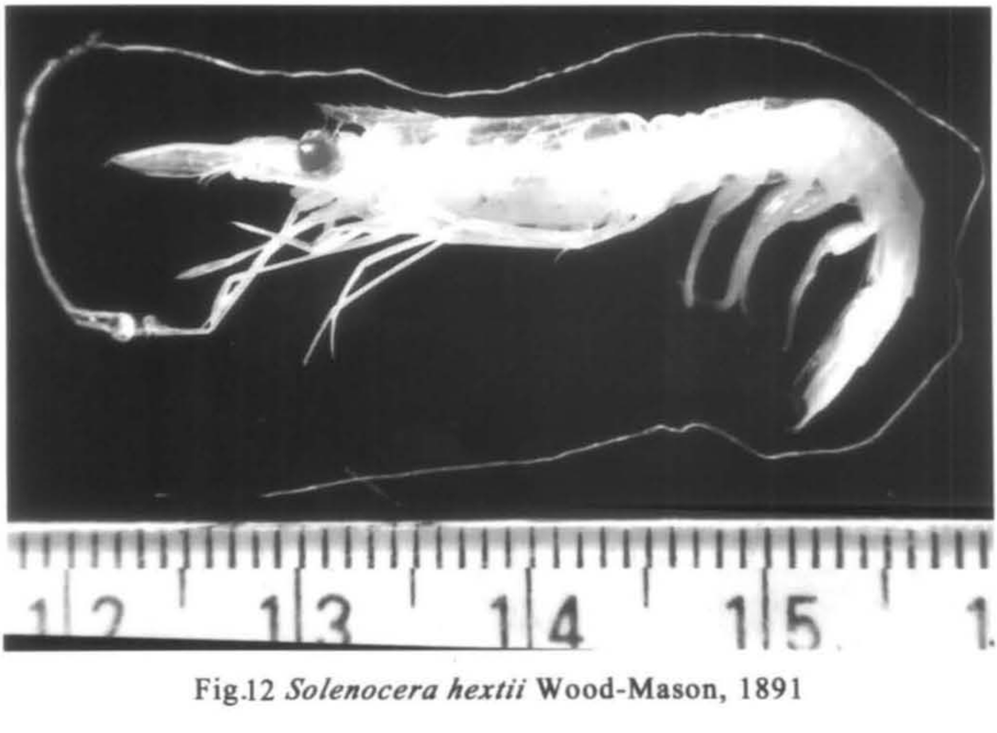

Fig.12 *Solenocera hextii* Wood-Mason, 1891

Super family : **SERGESTOIDEA** Dana, 1852

Family : **SERGESTIDAE** Dana, 1852

FEATURES OF THE FAMILY

Rostrum either very small (or) absent, when present rostrum shorter than eye-stalk, supraorbital and hepatic spine present or absent. Antennal, branchiostegal and pterygostomian spines absent. Cervical sulcus well marked, weak or absent. Male ventral antennular flagellum modified to form clasping organs. Fourth and fifth pereopods reduced or absent. Males with large copulatory organs (Petasma) on first pair of pleopods (abdominal appendages). First to fifth abdominal somites dorsally rounded. Sixth somite weakly carinate.

Genus : ***Sergestes*** H.Milne Edwards, 1830

GENERIC CHARACTERS

Sergestes s.l (*Sergestes sensu lato*) with specialized luminescent modification of the gastro-hepatic gland (Organs of Pesta), but without dermal photophores. Supra orbital and hepatic spines may be present or absent in adults. Ovary confined to cephalothorax. Colour in life due to red subcuticular chromatophores mainly concentrated on anterior part of body (Yaldwyn, 1957).

9. ***Sergestes seminudus*** Hansen, 1919

Figure 13

Sergestes seminudus Hansen, 1919, p. 18 to 22, fig.7a-7c; George and Rao, 1966, p.328

Sergestes (Sergestes) seminudus Hansen: Yaldwyn, 1957, p.14, fig.10

MATERIAL EXAMINED

Specimen	: Many specimens
Locality	: Entire west coast of India
Depth of operations	: 50 - 350 m
Total length	: 26 - 46 mm

DESCRIPTION OF SPECIES

In fresh condition, "half-red" in colour and red stellate chromatophores spread all over body and appendages, but with a greater concentration on carapace and purplish-blue cuticular pigment occurred in dorsal surface of the carapace. Rostrum short and acute, hepatic spine present. Telson apically acute, with a pair of minute lateral spinules near apex and a pair of denticles on postero-lateral margin. Cervical groove well defined dorsally and laterally, almost continuous anteriorly with a well defined lateral ridge running from anterior to hepatic spine towards the base of the antenna. Suprabranchial groove and ridge prominent with a slightly less prominent horizontal ridge laterally across the branchial region.

In petasma, slender lamina externa of pars externa shorter than processus uncifer, processus ventralis basalis conical and acute. Processus ventralis long with a broad base and acute process distally. Lobus armatus do not project beyond processus ventralis observed by Hansen 1919, but falls a little short of latter (George and Rao, 1966), its whole inner margin has a row of about 10 hooks. Lobus inermis as broad as lobus terminalis at base, but tapering to a sub-acute tip and without hooks. Two small sharp teeth present on third coax of female.

DISTRIBUTION

Arabian Sea; Indonesia; eastern Australia; Japan; northwest Pacific Ocean and New Zealand.

10. *Sergestes semissis* Burkenroad, 1940

Figure 14

Sergestes semissis Burkenroad, 1940: 42-43; Judkins, 1978, p. 21-22, fig. 14, 15, 21b
Sergestes(Sergestes) semissis Burkenroad : Yaldwyn 1957, p. 8

MATERIAL EXAMINED

Specimen	: Many specimens
Locality	: Entire west coast of India
Depth of operations	: 50 - 400 m
Total length	: 15 - 35 mm

DESCRIPTION OF SPECIES

Rostrum short directed forward and somewhat upwards nearly obliquely triangular. Supra orbital spine and hepatic spines present. Gastro hepatic groove well developed. Segments with outer uropod setose along outer margin. Third maxilliped much longer than third pereiopod, dactylus with six subsegment and two terminal spines. Fifth pereopod without setae on leading margins of two distal segments.

Third maxilliped dactylus, with single mesial spines on outer margins of first and second subsegment. Outer distal spine on first subsegment usually not reaching beyond midpoint of second subsegment; outer distal spine on second subsegment usually not reaching much beyond juncture of third and fourth subsegment.

Male petasma, lobus inermis stout and with small projection at about midpoint of mesial margin. Lobus terminalis, the anterior lobe cylindrical armed distally with single, large exposed hook, posterior lobe stout thaumb like, unarmed, directed posteriorily. Lobus connectons, thumblike anteriorly with lateral row of large hooks. Lobus armatus bilobed. Processus ventralis covered distally with numerous minute hooks.

DISTRIBUTION

Arabian Sea; Bay of Bengal; Northern Mozambique.

11. *Sergestes orientalis* Hansen, 1919

Figure 15

Sergestes orientalis Hansen, 1919: 22-26, PL 2: Fig .2; Judkins, 1978: 23-25, Fig .16

MATERIAL EXAMINED

Specimen	: Many specimens
Locality	: Entire west coast of India
Depth of operations	: 50 - 350 m
Total length	: 15 - 35 mm

DESCRIPTION OF SPECIES

Rostrum short, directed forward and somewhat upwards nearly obliquely triangular. Supra orbital spine and hepatic spines present. The gastro hepatic groove well developed. Third maxilliped much longer than third pereopod, dactylus with six sub segment and two terminal spines. Fifth pereiopods without setae on leading margins of two distal segments. Outer uropod setose along its outer margins.

In male petasma, with lobus inermis gently inflected at proximomesial margin, distally bearing variable number of irregular protuberances, (Judkins, 1978) observed but here no irregular protuberances. Lobus terminalis, anterior lobe distally armed with large exposed hook. Posterior lobe cylindrical, elongate, distally armed with large recessed hook. Lobus connections having three lobes, middle lobe largest, inner and outer lobes about equal in size. All three bearing numerous hooks. Lobus armatus, bilobed, outer lobe short, and thumb-like.

DISTRIBUTION

Southwest Indian Ocean; Tropical Indian Ocean; Indo-Australian Archipelago; western tropical Pacifc Ocean; south-east Atlantic Ocean; Red Sea; Indonesia; south China Sea; north west Pacific Ocean; southeast Off South Africa; Hawaiian Island.

Genus : ***Sergia*** Stimpson, 1860

GENERIC CHARACTERS

Sergestes s.l. (*Sergestes sensu lato*) without specialized luminescent modifications of gastro-hepatic gland (Organs of Pesta). With or without dermal photophores which when present may or may not have cuticular lenses. Supraorbital and hepatic spines absent in adult (Secondary hepatic prominences may sometimes be present). Ovary may extend into abdomen. Adult with red cuticular pigment distributed over entire body and appendages throughout life (Yaldwyn, 1957).

12. ***Sergia inous*** Faxon, 1893

Figure 16

? *Sergestes inous* Faxon, 1893; Vol. XXIV, p.216; Hansen, 1919. Vol.38, p.9

Sergestes sp.? *inous* Faxon: Alcock, 1901, p.50

MATERIAL EXAMINED

Specimen	: Many specimens
Locality	: Entire west coast of India
Depth of operations	: 50 - 500 m
Total length	: 30 - 60 mm

DESCRIPTION OF SPECIES

Rostrum ascendant, very short. Carapace with no spines and distinct gastro-hepatic groove. Abdominal somite dorsally rounded. Outer border of exopodite setose only at distal fourth of tail fan, beyond a microscopic denticle. Eye black wider than the eyestalk and "smeared with black pigment". Antennular peduncle robust in all, its joints its first segment being slightly longest of three and being hollowed for edges. Antennal scale with tip rounded and outer edge hardly thickened, ends in a microscopic spinule. No dermal photophores present on body (or) appendages. The body colour ghastly red due to distribution cover entire body of a red pigment carried in the cuticle. Organ of pesta and dermal photophores absent.

DISTRIBUTION

Southwest Indian Ocean; Tropical Indian Ocean; Indo-Australian Archipelago; western tropical Pacific; southeast Atlantic Ocean; Red Sea; Indonesia; south China Sea; northwest Pacific Ocean; southeast Off South Africa and Hawaiian Island.

Genus : ***Acetes*** H. Milne Edwards, 1830

GENERIC CHARACTERS

species of *Aectes* small, body translucent or semi translucid. Abdomen dorsally rounded. Rostrum short, with one or more dorsal denticles. Carapace with strong supra orbital and hepatic spines present. Lower antennular flagellum in males with clasping organs. Three parts being recognizable for all species, segmented basal shaft, inner multi segmented main branch and outer clasping spines. Third maxilliped shorter than third pereopod. First pereopods with small chela. Pereropods four and five absent.

13. ***Acetes japonicus*** Kishinouye, 1905

Figure 17

Acetes japonicus Kishinouye, 1905,167

Acetes dispa, Hansen, 1919, 39; Nataraj, 1947. 145

MATERIAL EXAMINED

Specimen	: Many specimens
Locality	: Lat. 16° 78'N - Long. 73° 85'E
Depth of operations	: 30 m
Total length	: 20 - 25 mm

DESCRIPTION OF SPECIES

Body translucid. Abdomen dorsally rounded. Rostrum short, with two dorsal denticles. Supra-orbital and hepatic spines present. First pereopod with small chela. Pereropods four and five absent. In females, Apex of telson rounded or truncated and third thoracic sternite produced posteriorly. In males lower antennular flagellum with two clasping organs. First segment of main branch of lower antennular flagella without triangular projection.

DISTRIBUTION

India to Japan; Java; Indonesia; China; and Korea.

Fig. 13 *Sergestes seminudus* Hansen, 1919

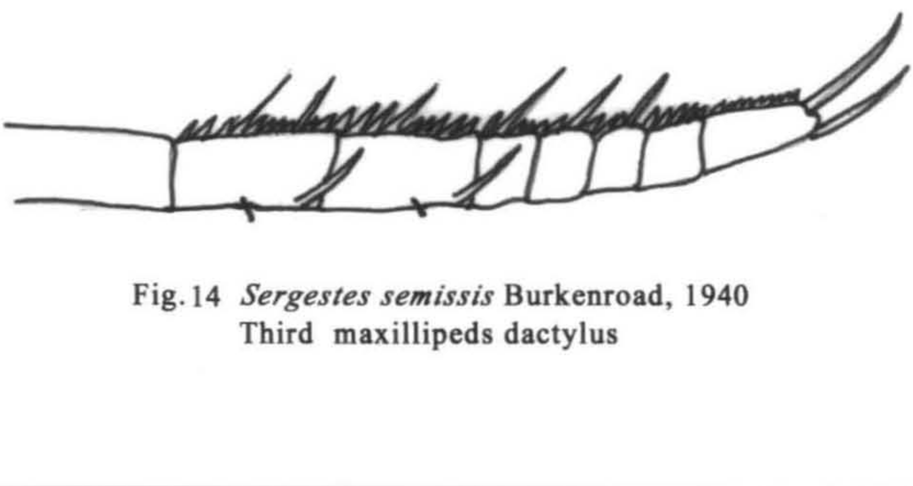

Fig. 14 *Sergestes semissis* Burkenroad, 1940
Third maxillipeds dactylus

Fig. 15 *Sergestes orientalis* Hansen, 1919

Fig. 16 *Sergia inous* Faxon, 1893

Fig. 17 *Acetes japonicus* Kishinouye, 1905

Family : **LUCIFERIDAE** De Haan, 1849

Genus : ***Lucifer*** Thompson, 1829

FEATURES OF THE FAMILY AND GENERIC CHARACTERS

Pelagic forms, rostrum short, spiniform. Carapace strongly compressed. Region between bases of eye, antennae and mouthparts elongate. Antennule lacking lower flagellum in both sexes. Mandibles and maxillae without palp, with exopod in form of small plate. First maxilliped lacking epipod and exopod. Second maxillipeds lacking epipod. First to third pair of legs present and only third pair chelate (imperfectly). Gills entirely absent. Sixth abdominal segment in male with two ventral processes, unarmed in female. Telson in male with ventral process, no such processes in female. Single genital opening in both sexes. In male, petasma sessile, attached proximally to first pleopodal peduncle. Second pleopod in male with unilamellate appendix masculina.

Monogenerics. Pelagic. The only decapod crustacean without gills.

Remarks : The position and relationships of the Luciferidae are problematic, as was pointed out by Burkenroad (1983: 284). Although he included the group in the Dendrobranchiata, they possess none of the features that he used to characterize this suborder, other than that they hatch as free nauplii [generally agreed to be a primitive feature; see Kaestner, (1970: 53]. Traditionally regarded as a subgroup of the Sergestoidea, the placement of *Lucifer* within the Penaeidea was based on the presence of a petasma in the male (a feature also found in the eumalacostracan order Euphausiacea), while the absence of pereopods 4 and 5 was seen as indicating its relationship to the sergestids: *Acetes*, for examble, also lacks pereopods 4 and 5. The assumption implicit here is that loss of pereopods 4 and 5 is a synapomorphic feature of the Luciferidae and the Sergestidae, rather than two events that occurred independently. However, the advanced features that characterize the Luciferidae, namely the extreme compression of the body, the lack of chelae, the absence of a ventral antennular flagellum, the absence of mandibular and maxillar palps, the retension of eggs on the third pleopods of the female, and the absence of gills, suggest that loss of the two posterior pereopods was part of the suite of extreme modifications for a highly specialized planktonic existence. Further, the complete lack of gills in *Lucifer* negates the most basic feature for inclusion in the Dentrobranchiata (Perez Farfante and Kensley, 1997).

14. *Lucifer typus* H.Milne - Edwards, 1837

Figure 18

Lucifer typus H.Milne Edwards, 1837: Hansen, 1919: 53, pl.4, fig.6; Kensely, 1971a,p. 223, fig. 2a,b,c,d; Perez Farfante and Kensley, 1997, p.184, fig.126 and 127

MATERIAL EXAMINED

Specimen	: Many specimens
Locality	: Entire west coast of India
Depth of operations	: 10 - 750 m
Total length	: Maximum 13 mm

DESCRIPTION OF SPECIES

Length of eye including eye-stalk less than distance between eye-stalk base and labrum. Anterior ventral process on sixth abdominal segment in male almost as long as posterior, slender process, while swollen distal part of posterior process is bent considerably upwards. Spine on outer margin of outer uropod ramus extending well beyond apex. Petasma with terminal portion robust, sheath apically blunt. Sheath with transverse lines on outer surface, enclosing broad processus ventralis and a strong hooked process. Processus ventralis with two terminal spines separated by a straight edge. Petasma with process ventralis has transverse area between two horns.

DISTRIBUTION

Bay of Bengal; northeast Pacific Ocean; Off Baja California; Off new Foundland; northwest Atlantic Ocean Off USA; Sargasso Sea; Brazil; northeast Atlantic Ocean; Mediterranean; southeast Atlantic Ocean off Cape of Good Hope ; east coast of South Africa; Philippines; Queensland; Australia and eastern Central Pacific Ocean.

15. *Lucifer penicillifer* Hansen, 1919

Figure 19

Lucifer penicillifer Hansen, 1919: 59, pl.5, fig. 2; Barnard, 1947: 384; 1950: 645, fig.121; Kensley 1971, p.221. fig 1a-d

MATERIAL EXAMINED

Specimen	: Many specimens
Locality	: Entire west coast of India
Depth of operations	: 10 - 750 m
Total length	: Maximum length 10 mm

DESCRIPTION OF SPECIES

Length of eye about one third that of distance between base of eye-stalk and labrum. First antennular peduncle segment extending slightly beyond eye. Sixth abdominal segment in male with two ventral processes, second processes longer than first, apex acutely rounded. Telson in male with the rounded ventral process some distance from the apex, bearing numerous tiny granules. Tooth on outer margin of outer uropod ramus not extending beyond apex. Petasma with strongly chitonized sheath, outer convex portion of which bears numerous tiny spines, apex slightly expanded. Processus ventralis slender ending in a bipartite 'brush'.

DISTRIBUTION

Bay of Bengal; Malaysia; Indonesia; south China; Philippines; Hong Kong; Japan; northern Australia; southeast coast of South Africa; east African Coast; Gulf of Yeddo and east Indies.

16. *Lucifer hanseni* Nobili, 1905

Figure 20

Lucifer Hanseni Nobili : Hansen,1919, p.63, PL.V, fig 4a-4o,

MATERIAL EXAMINED

Specimen	: Many specimens
Locality	: Entire west coast of India
Depth of operations	: 10 - 750 m
Total length	: Maximum length 10 mm

DESCRIPTION OF SPECIES

Eye-stalk vary from a little more to conspicuously less than half as long as distance between their insertion and labrum. In both sexes, first antennular joint reaches a little beyond eyes. Male 6^{th} abdominal segment, first ventral process much shorter than 2nd, and very nearer to second process. Second process has a blunt end. In male petasma, processus ventralis, distal half curved, and acute needle-like.

DISTRIBUTION

Madagascar; Red Sea; India; south China Sea; Victoria and Australia.

17. ***Lucifer orientalis*** Hansen, 1919

Figure 21

Lucifer orientalis Hansen, 1919: 55, pl. 4, fig.7a-g; Kensley, 1971a, p. 219, fig. 2e.g; Omori, 1992, p.104, fig. 2, 3

MATERIAL EXAMINED

Specimen	: Many specimens
Locality	: Entire west coast of India
Depth of operations	: 10 - 750 m
Total length	: Maximum length 10 mm

DESCRIPTION OF SPECIES

Eye including eye-stalk slightly shorter than distance between eye-stalk base and labrum. First antennular peduncle segment reaching to proximal edge of cornea. Sixth abdominal segment in male with two ventral process, anterior process curved, apically narrowly rounded. Posterior process distally expanded, slightly flexed dorsally. Telson in male short, rounded ventral process ending distally at apex. Spine on outer margin of outer uropod ramus extending well beyond apex. Petasma with sheath consting distally of two pointed lobes, with transverse lines on outer surface, covering the process ventralis. Later consisting of two diverging pointed lobes.

DISTRIBUTION

East coast of South Africa; Red Sea; Indonesia; Malaysia to south China Sea; Philippines; eastern central Pacific Ocean.

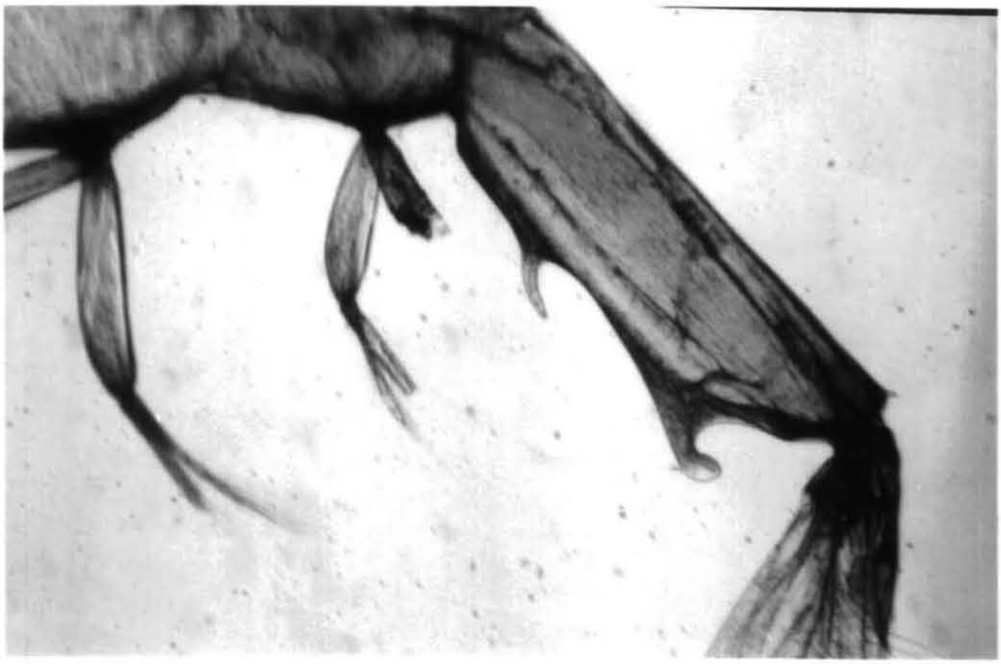

Fig. 18 *Lucifer typus* H. Milne Edwards, 1837
Male, sixth abdominal segment

Fig. 19 *Lucifer penicillifer* Hansen, 1919
Male, sixth abdominal segment

Fig. 20 *Lucifer hanseni* Nobili, 1905
Male, sixth abdominal segment

Fig. 21 *Lucifer orientalis* Hansen, 1919
Male, sixth abdominal segment

Super family : **OPLOPHORIDEA**

Family : **OPLOPHORIDAE** Dana, 1852

FEATURES OF THE FAMILY

Well-developed rostrum. Mandibles with three-jointed palp, molar and incisor process indistinctly separated. In second maxillipeds terminal joints attached laterally to penultimate. Small chelae present in first two pairs of thoracic legs. Carpus of second pereopod unsegmented. Telson acute. Exopods on all legs. Last three pairs of legs not as long as abdominal length.

Genus *: **Oplophorus*** H. Milne Edwards, 1837

GENERIC CHARACHTRES

Rostrum long, serrated dorsally and ventrally. Antennal and branchiostegal spine present on carapace. Abdomen more or less carinate, carinae of third, fourth and fifth terga produced backwards as long spines. Outer edge of antennal scale strongly serrated and tapering extremely acute. First two pairs of legs a little more robust than others and has well formed chelae. Exopods of atleast the third maxillipeds and first pair of pereopod foliaceous and generally rigid, outer margin of antennal scale usually armed with a series of spines, telson apicaly acute, eyes large and pigmented. Eggs large.

18. ***Oplophorus typus*** H. Milne Edwards, 1837

Figure 22

Oplophorus typus H..Milne-Edwards, 1837, p.424, fig.6,7; Bate, 1888, p.762, pl.127, fig.1; Chace 1936, p.30;Suseelan, 1984; fig 6 & 7

MATERIAL EXAMINED

Specimen	: Many specimens
Locality	: Entire West Coast of India
Deoth of operations	: 10 - 750 m
Total length	: 06 - 50 mm

DESCRIPTION OF SPECIES

Rostrum long, slightly upturned, dorsally armed with 10 to 14 teeth and ventrally 7 to 9 teeth (rarely less), its base buttressed by a sharp carina running to about middle of gastric region. Carapace with dorsal carina extending to posterior margin. Branchiostegal spine distinct with a well-defined keel, posterolateral angle with a ventrally directed tooth. Second to sixth abdominal terga carinated dorsally, carinae of third to fifth somites terminating posteriorly in sharp spines. Spine on third tergum much longer than those of fourth and fifth. Anterior border of pleura of first abdominal somites in male broadly cancave with the lower lobe more pronounced and narrow. Telson longer than uropod. Scaphocerite long, apex acute and pointed, inner margin simple. Third maxillipeds stout, extending to middle of scaphocerite, its basal article strongly arched externally. First two pairs of pereopods similar in form. Third pereopod longer than fourth and fifth. In adult male appendix masculina of second pleopod much longer than appendix interna. Colour of fresh specimens bright carmine pink.

DISTRIBUTION

Western Atlantic Ocean; West Indies; Indo-Pacific; Gulf of Aden; Zan zibar; Maldives; Arabian Sea; Bay of Bengal; Andaman Sea; Malay Archipelago; Philippines; New Guinea; Fiji Island and Hawaii.

Genus : ***Acanthephyra*** A. Milne Edwards, 1881

GENERIC CHARACTERS

Rostrum usually long and armed with teeth both dorsally and ventrally, rarely short. Carapace without oblique hepatic and straight keels. Abdomin with atleast last 4 segments dorsally keeled. Incisor process of mandible toothed along its entire length. Outer margin of antennal scale smooth and ending in a little spine. Eyes variable in size but well pigmented.

19. ***Acanthephyra sanguinea*** Wood-Mason, 1892

Figure 23

Acanthephyra sanguinea Wood-Mason, 1892 , p.358, fig.1; Alcock, 1901, p.79;
George and Rao, 1966; p.329

MATERIAL EXAMINED

Specimen	: Many specimens
Locality	: Entire West Coast of India
Depth of operations	: 10 - 750 m
Total length	: 30 - 75 mm

DESCRIPTION OF SPECIES

Rostrum long, upcurved with seven (or) eight dorsal and five (or) six ventral teeth extending much beyond tip of antennal scale. Branchiostegal spine small, forming a small projection on frontal border of carapace and without carina. Post antennal spine minute. Dorsal carina of third to sixth abdominal somites ending in pointed spines, that of third somite being longest and fourth and fifth equal and small. Four pairs of dorsolateral spines present on telson.

DISTRIBUTION

Indo-Pacific, from the gulf of Aden and east Africn Coast, Arabian Sea, Andaman Sea, and Bay of Bengal.

Genus : ***Meningodora*** Smith, 1882

20. *Meningodora* sp.

Figure 24

GENERIC CHARACTERS

Hind margin of hepatic groove abruptly cut off from branchial region by an oblique carina; anterior half incisor process of mandible unarmed. A single longitudinal carina on lateral surface of carapace; dorsal margin of carapace not denticulate on posterior three-fourth of its long; abdomen not dorsally carinate on first somite (Holthuis, 1955, Key only).

MATERIAL EXAMINED

Specimen	: Two male specimens
Locality	: Lat. 11° 26' - Long. 67° 34' and Lat. 14° 31' - Long. 67° 32'
Depth of operations	: 750 m
Total length	: 50 mm

DISTRIBUTION

South Philippines Island; Tristan da Cunha and Pernambuco.

REMARKS

Number of specimens under this genus is only six and all of which are with broken appendages/body parts. Hence it was not possible to identify them up to species level.

Fig. 22 *Oplophorus typus* H. Milne Edwards, 1837

Fig. 23 *Acanthephyra sanguinea* Wood-Mason, 1892

Fig. 24 *Meningodora* sp. Smith, 1882

Fig. 25 *Notostomus* sp. A. Milne Edwards, 1881

Super family : **NEMATOCARCINOIDEA**

Family : **NEMATOCARCINIDAE** Smith, 1884

FEATURES OF THE FAMILY

Well-developed rostrum. Flagella of both first and second antenna very long. Rostrum long, teeth present dorsally, occassionally articulate. Post antennular and branchiostegal spines present. Third abdominal tergum usually with a strongly convex posterior border. Telson long, tapering with well-developed spines at tip. A little spine present in tip of antennal scale. Mandibles deeply cleft between molar and incisor proceses, palp three jointed. Exopod and epipods present on first to fourth legs. Last three pairs of pereopods enormously lengthened; carpus of these legs several times longer than propodus. Dactylus of third and fourth leg spiniform; of fifth legs short, more or less concealed in a tuft of bristles.

Genus : ***Nematocarcinus*** A. Milne Edwards, 1881

GENERIC CHARACTERS

Rostrum long, dorsally serrated. Carapace with a post antennular and a branchiostegal spines. Third abdominal tergum usually with a strong convex posterior border. Telson tapering, with well-developed spines at tip. Antennular peduncle short, basal joint dorsally concave for eye and with a sharp scale at base of outer border. Antennular flagella are of very great length; outer one is a little thickened at base. Antennal scale long and narrow and ending a little spine. Third maxilliped shorter than any of legs. First two pairs of pereopods ending in small chelae, which a good deal concealed by tuft of setae of the second pair are a good deal longer than the first. Last three pairs rarely equal length and longer than second. All pleopods biramous, second to fifth pairs endopodite with usual internal appendix at its base.

22. *Nematocarcinus tenuirostris* Spence Bate, 1881

Figure 26

Nematocarcinus tenuirostris Bate, 1881, p.817.pl.cxxxii.fig.10;
Alcock, 1901, p.88

MATERIAL EXAMINED

Specimen	: Two male specimens
Locality	: Lat. 14° 31'- Long. 67° 32' and Lat. 17° 30' - Long. 70° 29'
Depth of operations	: 750 m
Total length	: 13 and 24 mm

DESCRIPTION OF SPECIES

Rostrum with nine dorsal teeth of which posterior three are close and the others separated from one another by intervals of increasing width. Rostrum, with its single ventral tooth placed some little way behind tip. Post antennal and branchiostegal spines sharp. Sixth somites longer than fifth. In one of last three pairs of legs, merus and carpus combined almost same length of whole body from tip of rostrum to the tip of telson.

DISTRIBUTION

Arabian Sea and Bay of Bengal.

Fig. 26 ***Nematocarcinus tenuirostris*** Spence Bate, 1881

Super family : **PASIPHAEOIDEA** Dana, 1852

Family : **PASIPHAEIDAE** Dana, 1852

FEATURES OF THE FAMILY

Rostrum small or absent, some times represented by a spine arising behind frontal margin. Mandibular palp present or absent, molar process absent. Exopod rudimentary or absent. First two pairs of legs longer and much stouter than others, chelae elongate, with slender fingers and thumbwrist short, unsegmented. Exopods on all legs, but no epipods. First pair of pereopods chelate or simple. Fingers of all four chelae slender, and their cutting edges pectinate.

Genus : ***Leptochela*** Stimpson, 1860

GENERIC CHARACTERS

Rostrum dorsally unarmed. Fourth pereopod shorter than third, both much shorter than first. Pleopods with exo and endopod short and about equal length. Sixth abdominal somite with transverse carinate ridge near the anterior end of dorsal surface and long fixed posterior directed spine near posterior end of ventrolateral margin. Telson with mesial pair of movable spines anteriorly, one or two pairs of dorsolateral movable spines and five pairs of prominent posterior movable spines, all but lateral pair (perhaps actually belonging to dorsolateral series) of latter minutely serrate on one or both lateral and mesial margins (Minute additional pair of spines, some time present between bases of median pair). Mandibular palp broad, flattened and undivided. Two arthrobranchs present in third maxillipeds. Fourth pereopod shorter than third, longer than fifth. Exopods of pleopods not unusally long. Both branches of uropod with series of movable lateral spines.

Sub genus : ***Leptochela (Leptochela)*** Stimpson, 1860

SUB GENERIC CHARACTERS

Sixth abdomianl somite without dorsal lappet. Telson with origins of anterior pair of dorsolateral spines and of anterior dorsal pair separated by a distance of atleast 1/5 length of telson, not excluding posterior spines. Antennal scale usually less than 2/3 of the carapace. Third pereopod with exopod not reaching nearly distal end of ischium. Fifth pair of pereopod at least 3/4 length of 4^{th} pair. (Chace, 1976)

24. *Leptochela (Leptochela) robusta* Stimpson, 1860

Figure 27

Leptochela robusta Stimpson, 1860: P.43; De Man, 1920, p.19, pls .iii. iv, fig.7-7x; Kemp,1925, p. 252

Leptochela (Leptochela) robusta Stimpson: Chace, 1976, p.34, fig. 28

MATERIAL EXAMINED

Specimen	: Many specimens
Locality	: Entire west coast of India
Depth of operations	: 10 - 751 m
Total length	: 10 - 30 mm

DESCRIPTION OF SPECIES

Rostrum variable, dorsal margin usually straight, concave. Telson with two pairs of dorsolateral spines in addition to anterior mesial pair and usual five pair of prominent spines present. Second legs with 37 to 42 spines on inner margin of dactylus and 45 to 50 on the fixed finger. Third pereopod, ischium armed with row of four stout spines near flexor margin, merus with six or seven longer stout spines near flexor margin. Appendix masculina (not including spines) overreaching appendix interna, size large.

DISTRIBUTION

China Sea; Off Cuba and the Sulu Archipelago in the Philippine Islands; north of Pulau Waigeo; Indonesia; Japanese waters; Maladives; Burma Coast; Andaman; Nicobars; northeast coast Australia; east Indian Archipelago and Red Sea.

23. *Leptochela (Leptochela) aculeocaudata* Paulson, 1875

Leptochela aculeocaudata Paulson, 1875: 100. Pl.16. fig 1-1s; Kemp, 1925, p.254
Leptochela (Leptochela) aculeocaudata Paulson: Chace, 1976, p.4. fig 2,3 &4

MATERIAL EXAMINED

Specimen	: Many specimens
Locality	: Entire west coast of India
Depth of operations	: 10 - 750 m
Total length	: 10 - 30 mm

DESCRIPTION OF SPECIES

Rostrum straight or slightly concave anteriorly. Telson with one pair of dorsolateral spines in addition to anterior mesial pair; posterior margin without pair of minute mesial spines in addition to usual five pair of prominent spines. Second pereopod with 18 to 25 spines on inner margin of dactylus and 21 to 28 on fixed finger.

Abdominal terga usually rounded on all somites; sixth somite longer than fifth, its low transverse carinate swelling at extreme anterior end and usually concealed beneath posterior margin of fifth somites; slightly curved spine on ventrolateral surface and distinct acute tooth on posteriodorsal margin of posterolateral lobe. Third pereopod extending beyond extreme margin of carapace; ischium bearing two spines near flexor margin; merus with three spines, carpus with one spine, dactylus much shorter than propodus.

DISTRIBUTION

Red Sea; Queens land; Australia; Andaman; Bay of Bengal and Arabian Sea.

Genus : ***Psathyrocaris*** Wood-Mason & Alcock, 1893

25. *Psathyroacris* sp. Wood-Mason & Alcock, 1893

Figure 28

GENERIC CHARACTER

Third and fourth pereopods slender, of about equal length and not shorter than first. Pleopods with exopod very long and narrow, endopod much shorter. Dorsal teeth present on rostrum. No spine on carapace. Acute telson. Mandibles with a large straight two-jointed palp.

MATERIAL EXAMINED

Specimen	: Two male specimens
Locality	: Lat 14° 31'N - Long 67° 32'E
Depth of operations	: 750 m
Total Length	: 35 mm

DISTRIBUTION

Bay of Bengal and Arabian Sea.

REMARKS

Only two male specimens under this genus and some body parts were in damaged condition. Hence, it was not possible to identify them up to species level.

Fig. 27 *Leptochela (Leptochela) robusta* Stimpson, 1860

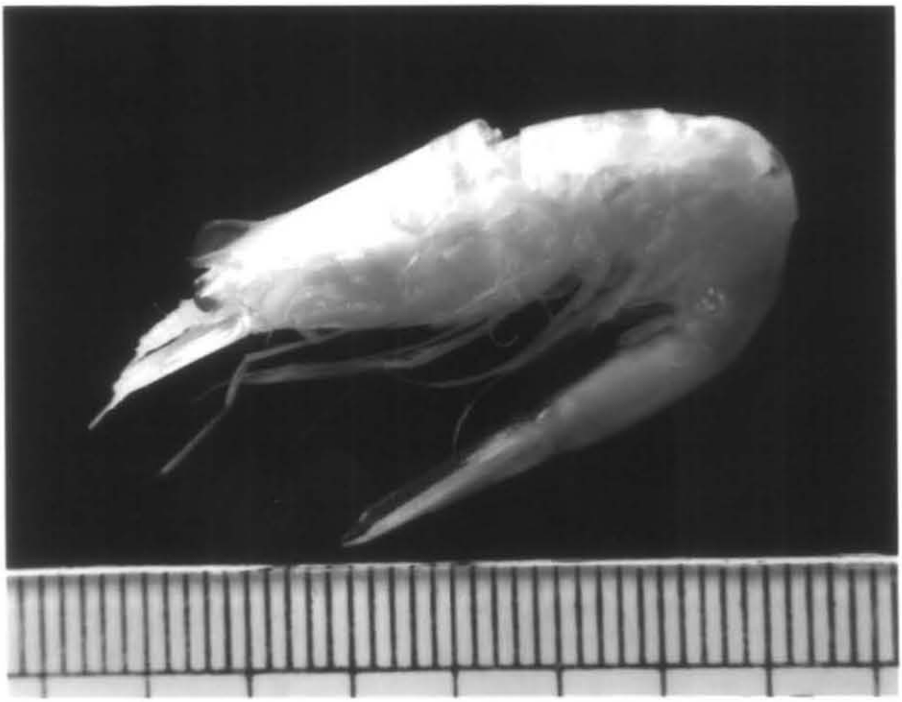

Fig. 28 *Psathyrocaris* sp. Wood-Mason & Alcock, 1893

Super Family : **PANDALOIDEA**

Family : **PANDALIDAE** Haworth, 1825

FEATURES OF THE FAMILY

Rostrum well developed. Mandible deeply cleft into molar and long incisor portion, palp usually consists of three segments. First maxillipeds have coxa and basis well developed, but coxa of second maxillae recedes. Terminal segment of second maxillipeds like a narrow plate attached along its extend to inner border of penultimate segment, as if it were a complemental piece of latter segments. First pair of legs imperfectively chelate. Second pair minutely chelate. Third to fifth legs long and slender. Telson acute.

Genus : ***Plesionika*** Bate, 1888

GENERIC CHARACTERS

Epipodites present on first four thoracic legs. Last three pair of legs long and slender. Rostrum usually at least as long as carapace; rostrum with atleast some fixed teeth dorsally and with or without teeth on ventral edge. Cornea large, often with an ocellus behind it. Third maxillipeds with exopod. Second pair of legs sub equal or conspicuously unequal. Posterior lobe of scaphognatite actually rounded.

26. ***Plesionika martia*** (A. Milne-Edwards), 1883

Figure 29

Plesionika martia var *semilaevis* De Man, 1920, p.116; Balss, 1925, p.278; Schmitt, 1926, p.377; Calmen, 1939, p.197; Chace, 1940, p.190; Barnard, 1947, p. 679

Plesionika martia George and Rao, 1966, p.330; Mohamad and Suseelan, 1973, p.629. fig.8.

MATERIAL EXAMINED

Specimen	:	Many specimens
Locality	:	Lat 7° 59'N - Long 76° 00'E
Depth of operations	:	280 m
Total Length	:	25 - 35 mm

DESCRIPTION OF SPECIES

Well developed and long rostrum, slightly upwards in a curve, armed above at base only with seven teeth, decreasing in size backwards. Posterior border of third abdominal tergum though convex, not actually produced. Ventral border of rostrum very closely and evenly serrated. Second pair of legs do not nearly reach tip of external maxillipeds and ocellus distinct. Post-antennal spine and sharp ptrygostomian spine present. Second pair of leg symmetrical, wrist multiarticulate. Appendix interna on male second pleopod oval with a patch of coupling hooks on its median surface. Appendix masculina ovate, inner margin strongly setose. Sixth abdominal tergum as long as telson and twice as long as fifth. External maxillipeds, little longer and stouter than first pair of thoracic legs.

DISTRIBUTION

Bay of Bengal and Arabian Sea

27. ***Plesionika alcocki*** Anderson, 1896

Figure 30

Plesionika alcocki Anderson, 1896,Vol LXV, p.92.

Plesionika (Plesionika) alcocki Anderson: Alcock, 1901 p.97

MATERIAL EXAMINED

Specimen	: Many specimens
Locality	: Entire west coast of India
Depth of operations	: 350 m
Total Length	: 26 - 35 mm

DESCRIPTION OF SPECIES

Rostrum long and well developed, armed dorsally, at its basal end with six teeth, three movable and very small and close each other on gastric crest, with two large isolated ones just in front of them. Armed throughout ventrally, beyond antennular peduncle. Telson shorter endopodite of caudal fin. First pair of legs not shorter than external maxillipeds. Second pair slightly unequal length in males. Their chelae have no conspicuous tufts of setae.

DISTRIBUTION

Arabian Sea, Off the south and southwest coasts of India

Fig. 29 *Plesionika martia* (A. Milne-Edwards) 1883

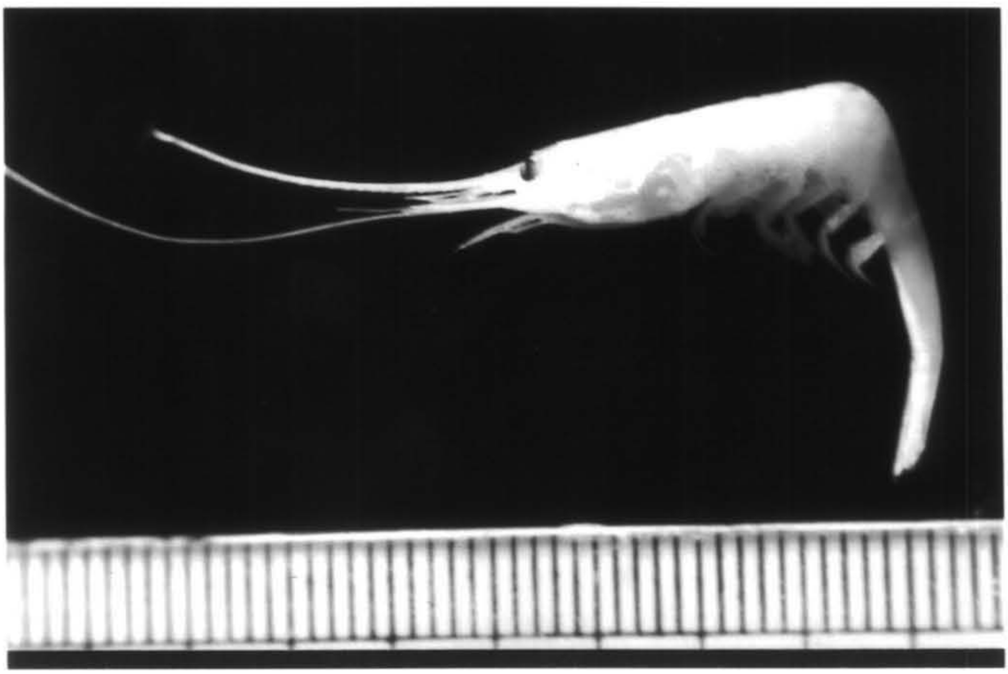

Fig.30 *Plesionika alcocki* Anderson, 1896

Family : **THALASSOCARIDIDAE** Bate, 1888

FEATURES OF THE FAMILY

Laterally compressed rostrum. Carapace dorsally smooth. Abdominal segment narrow, laterally compressed. Telson , tapering at a point. First pair of antennae having a stylocerite and terminating in two flagella. Second pair of antennae furnished with a scaphocerite. Carapace of second pair of pereopods not subdivided. Chelae of second pair of pereopod heavy and robust.

Genus : ***Thalassocaris*** Stimpson, 1860

GENERIC CHARACTERS

Supra orbital spine present. A series of spines present on outer border of antennal scale. A palp of three segments found on mandibles and posterior lobe of scaphognathite rounded. Exopod and epipod present in first three maxillipeds. Epipod present on first three pereopod. Arthrobranchs present on first four pereopods. Second pereopod equal; carpus stout and not divided into subsegments and chela is usually large. Third abdominal somite posteriorly produced to a large dorsal tooth.

28. ***Thalassocaris crinita*** (Dana), 1952

Figure 31

Regulus crinitus Dana, 1852, p.599. Pl.xxxiv, fig.6a-h

Thalassocaris crinita, De Man, 1920, p.95, pl.ix,fig.22.220; Kemp, 1925, p.284

MATERIAL EXAMINED

Specimen	: Many specimen
Locality	: Entire west coast of India
Depth of operations	: 10 - 400 m
Total length	: 5 - 15 mm

DESCRIPTION OF SPECIES

Rostrum shorter than carapace. Nine or ten teeth on dorsal side of rostrum and ventral side with three teeth. Antennal scale shorter than carapace and two teeth on outer margin of antennal scale rarely three. Second pair of pereopod reaching end of antennal scale, with strong tuberculation on edges of merus. Third abdominal somite posteriorly produced to a large dorsal tooth. Telson rather longer than sixth somite and gradually tapering to a point.

DISTRIBUTION

Arabian Sea.

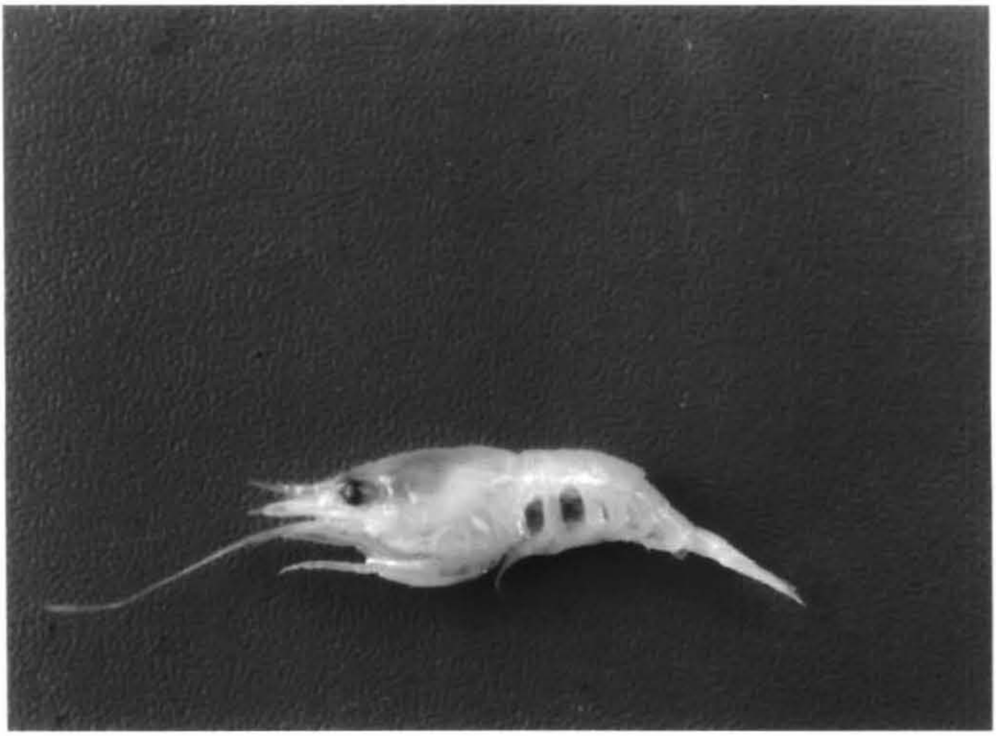

Fig. 31 *Thalassocaris crinita* (Dana) 1952

Infra order : **STENOPODIDEA**

Family : **STENOPODIDAE**

FEATURES OF THE FAMILY

Pleura of second abdominal somite not overlapping those of first segment. First three pairs forming a pincer. Third pair huge and massive. Third legs distinctly stronger than preceding. Males without petasma. Gills trichobranchiate.

Genus : ***Stenopus*** Latreille, 1819

29. *Stenopus* sp

Figure 32

GENERIC CHARACTERS

Dactylus of fourth and fifth periopod biunguiculate, short. Carapace and abdomen dorsally covered with uniformly distributed strong spines, sometimes arranged in longitudinal rows. Spines erect, curved forward. Ischium of third maxilliped with external spines (Holthuis, 1955 Key only).

MATERIAL EXAMINED

Specimen	: One specimen
Locality	: Latitude 16° 29' N - Longitude 73°35'E
Depth of operations	: 30 m
Total Length	: 15 mm

DISTRIBUTION

Fist record from the west coast of India.

REMARKS

Only one specimen under this genus with broken appendages. Hence, it was not possible to identify up to species level.

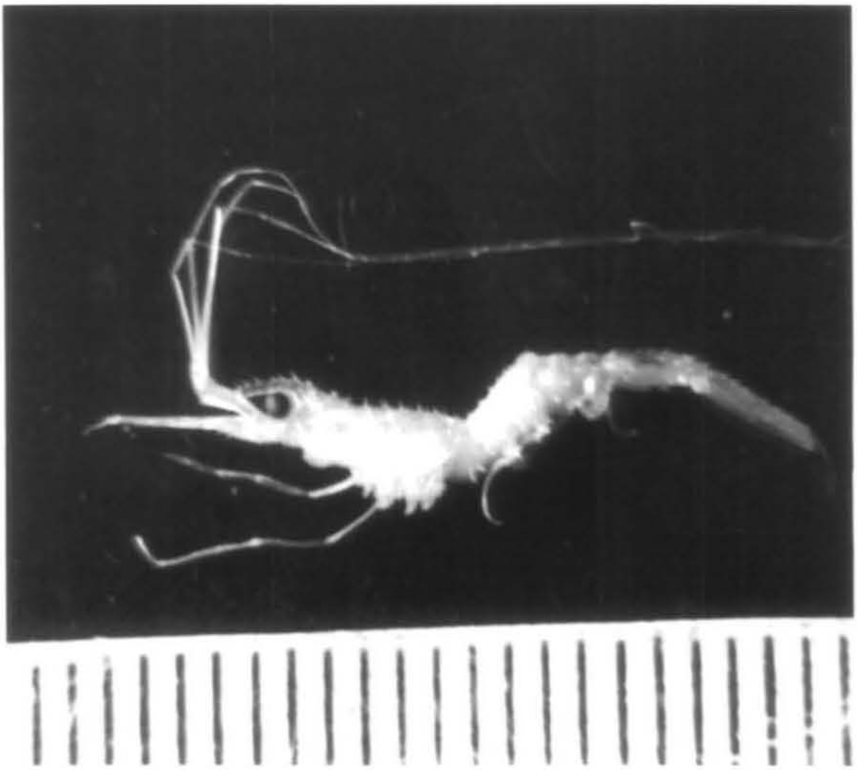

Fig. 32 *Stenopus* sp. Latreille, 1819

CHAPTER 3

DISTRIBUTION, ABUNDANCE AND BIOMASS OF PELAGIC SHRIMPS IN THE DSL

CHAPTER 3

DISTRIBUTION, ABUNDANCE AND BIOMASS OF PELAGIC SHRIMPS IN THE DSL

3. 1 INTRODUCTION

Since the time of Challenger Expedition (1873-76), the occurrence of bright red pelagic shrimps in the mid and deep waters of the ocean has been known. Recently much attention has been paid to discover their role in the productivity of the ocean. Possibly, shrimps link zooplankton with large animals of the higher trophic levels in the food chains and they transport much of the organic matter produced in the upper layers to the lower layers through their vertical migrations (Omori, 1974; Suseelan and Manmadan Nair, 1990). Generally pelagic shrimps are distributed unevenly, both vertically and horizontally. Capability of certain micro nektonic animals to avoid nets by visual perception during daytime is pronounced at shallow depth, as confirmed by Pearcy and Laurs (1966).

Nybakkan (1988) reported that the pelagic division of the ocean contains an upper zone immediately below the photic zone, which is inhabited by various organisms, many of which migrate vertically into the photic zone at night. These are variously called "twilight", "disphotic", or mesopelagic zone. This zone contains many species of animals with well-developed eyes and a great variety of light organs. The colouration adopted by fishes that reside here are black while the crustaceans are coloured red. Here the number of organisms appears to be highest, among all the deep-sea pelagic zones. This zone extends down to about 700-1000 m, its depth varying with location, density of water and other factors. Young (1983) opined red pigmentation of crustaceans would tend to protect these animals from the revealing rays and bioluminescent flashes used by predators.

Most of the pelagic animals in the ocean are limited in their vertical distribution to definite ranges of depth and many of these zooplanktons and fishes are known to undertake characteristic vertical migrations downwards to deeper waters during daytime and will return to surface waters in the evening. The diurnal migration appears to be more closely correlated with changes in the amount of light penetrating from the surface than with any other known factor of the environment (Cushing, 1951). Off the continental shelf, net hauls have shown that certain species of crustacean carryout diurnal migrations and their movement extend as deep as 800 m (Waterman *et al.*, 1939). In addition, echo sounder records have revealed the widespread occurrence of "Deep Scattering Layer" commonly at depths of 400 m to 600 m during the day time but also are observed at depths as deep as 1000 m (Moore, 1950).

The geographical distribution is also the product of the mobility of populations, the selective pressure and the time during which a taxon has existed. A taxon consists of a population or a group of populations, sufficiently distinct to be provided with a name, to be ranked in a definite category and to establish a geographic distribution. In a broad sense, mobility of populations doesn't merely depend on migration and transport alone, but reproduction, mortality and population dynamics also influence the mobility. In that sense, mobility comprises all phenomenon of movement, including the changes in number of specimens present at a locality. Vertical migration is the phenomenon in which organisms perform a shift in depth of occurrence at a fixed period or at several periods in their lifetime. This results in preference of a particular depth by population.

According to Vinogradov (1970) four ecological types of migration are distinguished, they are 1) the diurnal, 2) the ontogenetic, 3) the seasonal and 4) the feeding migration. Vanderspoel (1983) divided the four in to seven categories as: 1) diurnal migration 2) diurnal + seasonal migration 3) seasonal + ontogenetical migration

4) ontogenetical migration 5) diurnal + ontogenetical migration, 6) irregular feeding migration and 7) abyssal fauna migrations. The concentration of shrimps is particularly great in waters where the bottom slopes steeply. Usually frequent upwelling of deep waters can be expected to shift the isotherms upward in the regions and these results in the concentration of meso and bathy pelagic shrimps.

Pelagic decapods (Crustacea: Natantia) form significant and often spectacular part of the mesopelagic fauna of the ocean. They are usually well represented in mid-water collections. The section caridea includes the important and exclusively pelagic family, the Oplophoridae, while other pelagic forms that occur in the DSL of west coast of India belongs to families Penaeidae, Benthsicymididae, Solenoceridae, Sergestidae, Luciferidae, Nematocarcinidae, Pasiphaeidae, Pandalidae, Thalassocarididae and Stenopodidae.

The pelagic shrimps form important forage of oceanic tunas, flying fishes, etc. (George and George, 1964; George and Paulinose, 1973; James *et al.*, 1987) and a number of fish species inhabiting the shelf waters which support commercial fisheries (Nataraj, 1947; Chacko, 1949; Venkatramen, 1960; Suseelan and Manmadan Nair, 1990).

The pelagic shrimps are considered to be potentially important deep-sea pelagic shrimps occupying the outer shelf and slope waters of the west coast of India. Considering the commercial prospects of the pelagic shrimps, a detailed investigation was carried out for understanding its pattern of distribution, abundance, biomass and the resource characteristics in the DSL.

3.2 MATERIALS AND METHODS

The Pelagic shrimps collections were carried out by Isaacs - Kidd Mid water Trawl (IKMT) during May 1998 - December 2000 on boards FORV *SAGAR SAMPADA* in the area between 6°- 21°N and 66°- 77°E.

Pelagic shrimps were identified up to family level and were seperated from the DSL sample consisting of zooplanktons and micronekton. They were then counted and biomass in numbers/1000m^3 was calculated.

The biomass of pelagic shrimps was estimated using 'Swept area' method. Sparre and Vanema, (1992). The average biomass per unit area was estimated using the equation:

$$B = \frac{(Cw/a) * A}{x_1}$$

Where,

Cw = Catch in weight of a haul,

a = The area Swept by the gear during one unit of effort computed from the equation

$$a = t * v * h * x_2$$

Where,

t = time equal for trawling

v = velocity of trawling (3 knots)

h = average head rope length of IKMT

x_2 = effective net opening which was taken as 0.5 as suggested by Pauly (1983).

A = total area swept and

X_1 = portion of biomass actually retained by the gear (taken as 0.5 here).

The biomass in tonnes in 1^0 squares was calculated by taking into consideration the DSL thickness (in metres), the average biomass (gm/1000 m^3) of the collections were taken from that area and these have been extrapolated to compute the biomass for 1^0 squares.

3. 3 RESULTS

3.3.1 GEOGRAPHICAL DISTRIBUTION AND ABUNDANCE OF PELAGIC SHRIMPS

Pelagic shrimp catches were recorded from 123 stations (hauls) (88%) out of the total 140 IKMT stations (67 night hauls and 56 day hauls). The average pelagic shrimp biomass varied from 0.04 to 106.4 nos./1000 m^3. The maximum biomass was recorded at 08–74 degree squares (106.4 nos./1000 m^3) off Vizhinjam region.

The values for each 1^{o} squares were plotted (Figure 33) and it is seen that the distribution of pelagic shrimps shows a clear North-South variations with abundance increasing from North to South. The pelagic shrimps of the southwest coast (06^{o}-15^{0} N) accounted for about 64.75% of the total catch. The maximum population density was recorded off Vizhinjam (106.4 nos./1000 m^3), followed by off Cochin (100.8 nos./1000 m^3). The catches of the northwestcoast (15^{0} - 22^{0} N) formed about 35.26% and high catches were recorded off Ratnagiri region (51.1 nos./1000 m^3).

Generally the pelagic shrimps were concentrated more in area between 6^{0} - 10^{0} N and 16^{0} - 17^{0} N (Table 1) with maximum abundance (nos./1000 m^3) at 8^{0} N latitude (56.2 nos./1000 m^3) followed by 17^{0} N latitude (35.9 nos./1000 m^3) and 10^{o} N (35.7 nos./1000 m^3).

Day night variations in abundance

The pelagic shrimp catches were more during night than day (Table.1) It is very clear, that the night catches were more in the lower latitudes (6^{o}– 10^{o}N) than the higher latitudes. Distinct diurnal migration of pelagic shrimps in Indian seas is evident from the daynight variations observed in the catch of the IKMT hauls (Suseelan and Manmadan Nair, 1990).

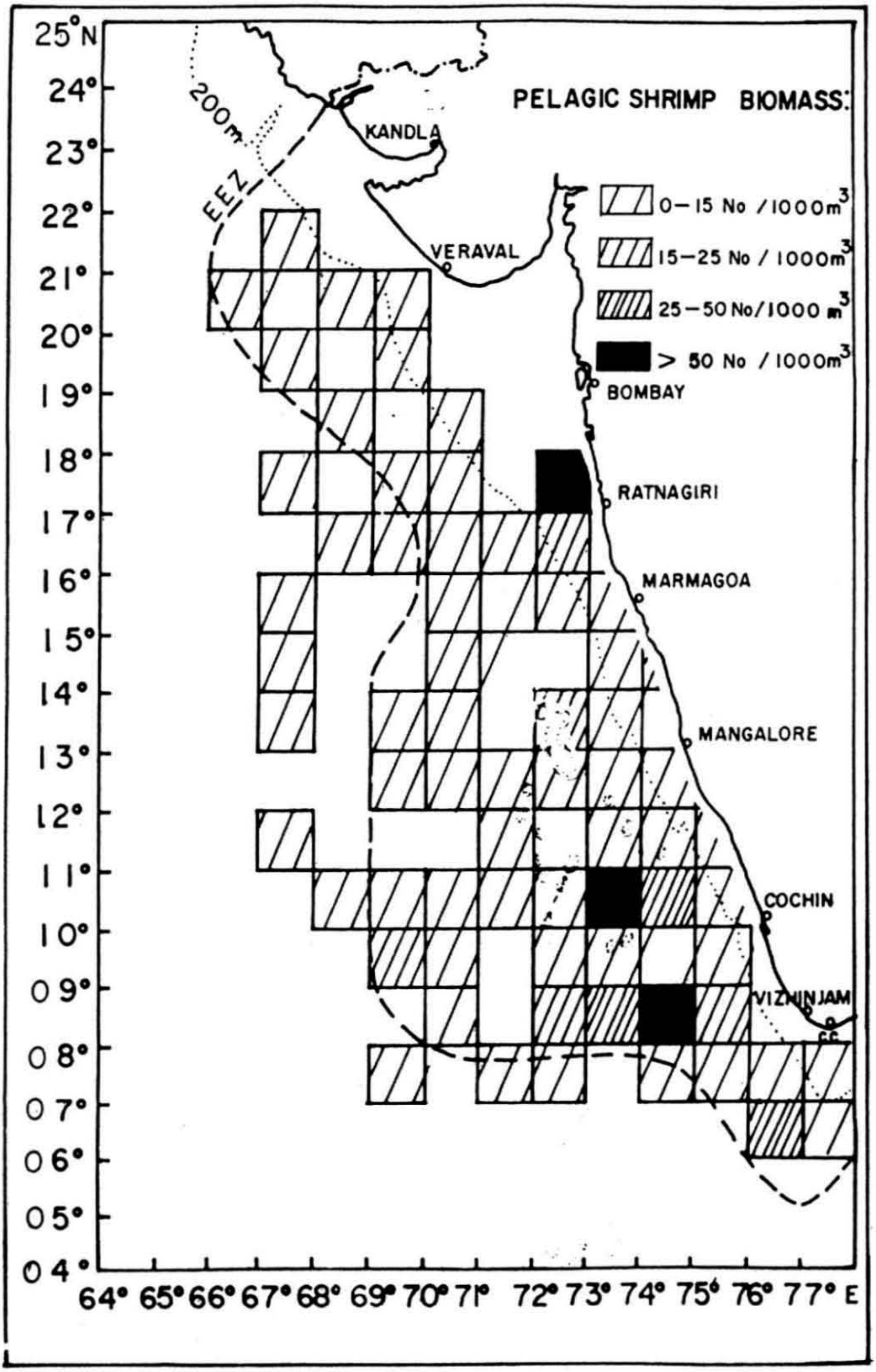

Figure 33. Geographical distribution and abundance (nos.1000m^3) of pelagic shrimps in the DSL in the west coast of India (Day and Night combined).

Table 1. Latitudewise day and night variations in abundance (nos./1000 m^3) of pelagic shrimps in different regions of west coast of India

LATITUDE	TOTAL	DAY	NIGHT
6°	32.1	3.6	28.5
7°	6.5	3.8	2.7
8°	56.2	13.7	42.5
9°	13.2	1.8	11.4
10°	35.7	5.1	30.6
11°	3.4	3.4	-
12°	7.4	2	5.4
13°	14.9	9.3	5.6
14°	8.1	8.1	-
15°	5.7	1.1	4.6
16°	14.5	0.4	14.1
17°	35.9	32.3	3.6
18°	0.4	0.2	2
19°	2	-	2
20°	6.1	0.47	5.6
21°	0.97	0.97	-

Day

Out of the total 123 hauls, there were 56 day hauls (45.5%). The maximum abundance was recorded at 17–72 degree squares (51.12 nos./1000 m^3) off Ratnagiri region. Geographical abundance (nos./1000 m^3) of the pelagic shrimps in the DSL during day is given in Figure 34.

The pelagic shrimp catches from the southwest coast formed about **73%** of the total biomass, with maximum density recorded off Vizhinjam (25.6 nos./1000 m^3). About **27%** of the total catches were obtained from the northwest coast with maximum catches off Ratnagiri (51.12 nos./1000 m^3/).

Latitudewise (Table 1), maximum biomass values were recorded between 17° - 18° N with an average of 32.3 nos./1000 m^3 and reasonably high averages were also observed along 08° N latitude (66° - 76° E) having value of 13.7 nos./1000 m^3.

Night

A total of 67 nights hauls (54.5%) were made during the cruises. The pelagic shrimp dominant areas were 10 – 73 degree squares (112.5 nos./1000 m^3) off Cochin, 10 – 74 degree squares (56.27 nos./1000 m^3) off Cochin and 08–74 degree squares (106 nos./1000 m^3) off Vizhinjam. The geographical abundance (nos./1000 m^3) of DSL pelagic shrimps in night collection was shown in Figure 35.

In the southwest coast, pelagic shrimps formed 92% of the total biomass with maximum density obtained from off Cochin (112.5 nos./1000 m^3). About 8% of the biomass was contributed by the catches from the northwest coast with maximum numbers formed off Ratnagiri (37.3 nos./1000 m^3).

Latitudewise (Table 1), fairly good catches were obtained throughout 08° N latitude (66° –77°E) and 10° N latitude (66° –76°E) having average value of 42.5 nos./1000 m^3 and 30.6 nos./1000 m^3 respectively.

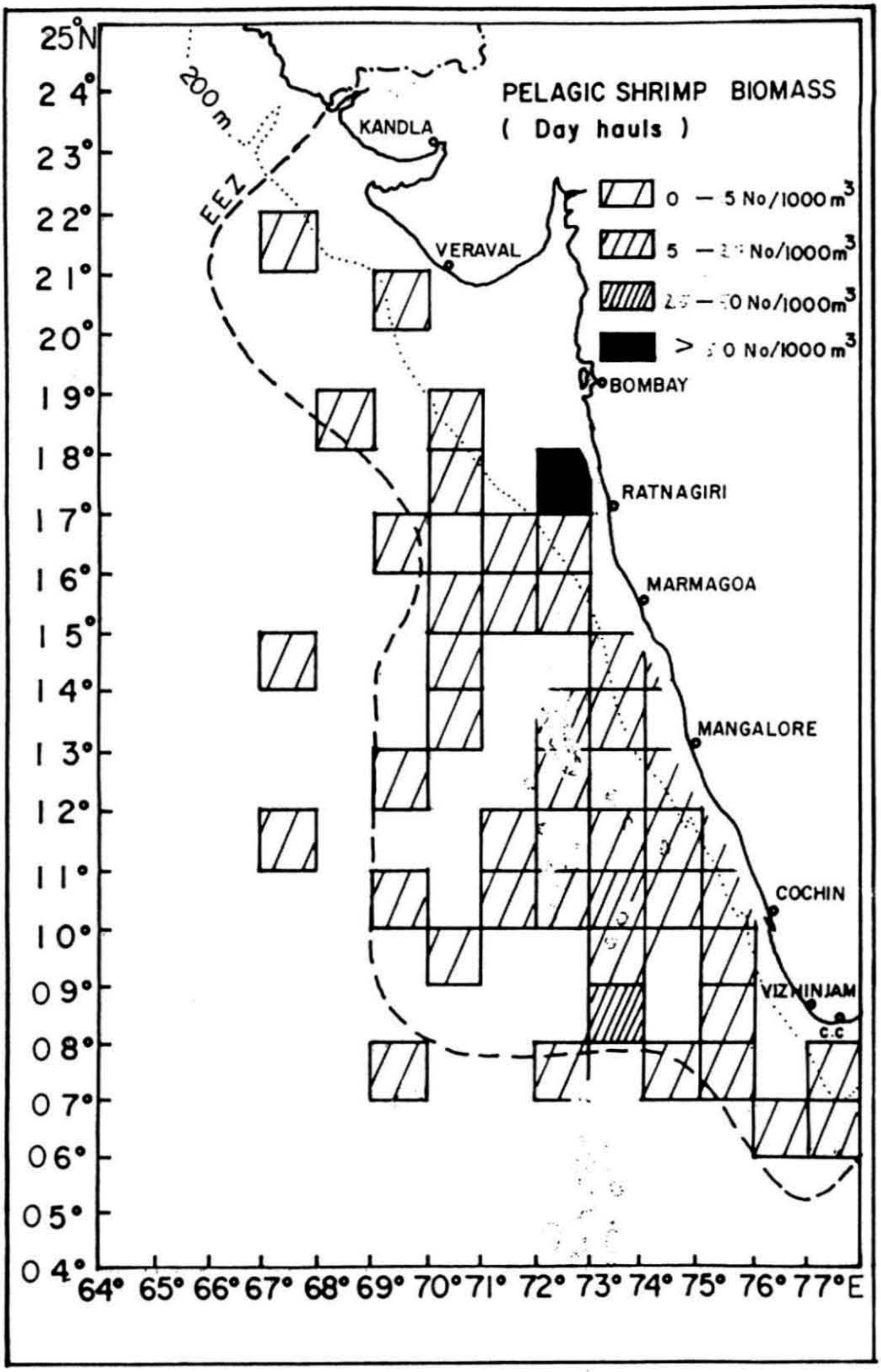

Figure 34. **Geographical distribution and abundance (nos./1000 m^3) of pelagic shrimps from the day hauls of IKMT in the DSL of the west coast of India.**

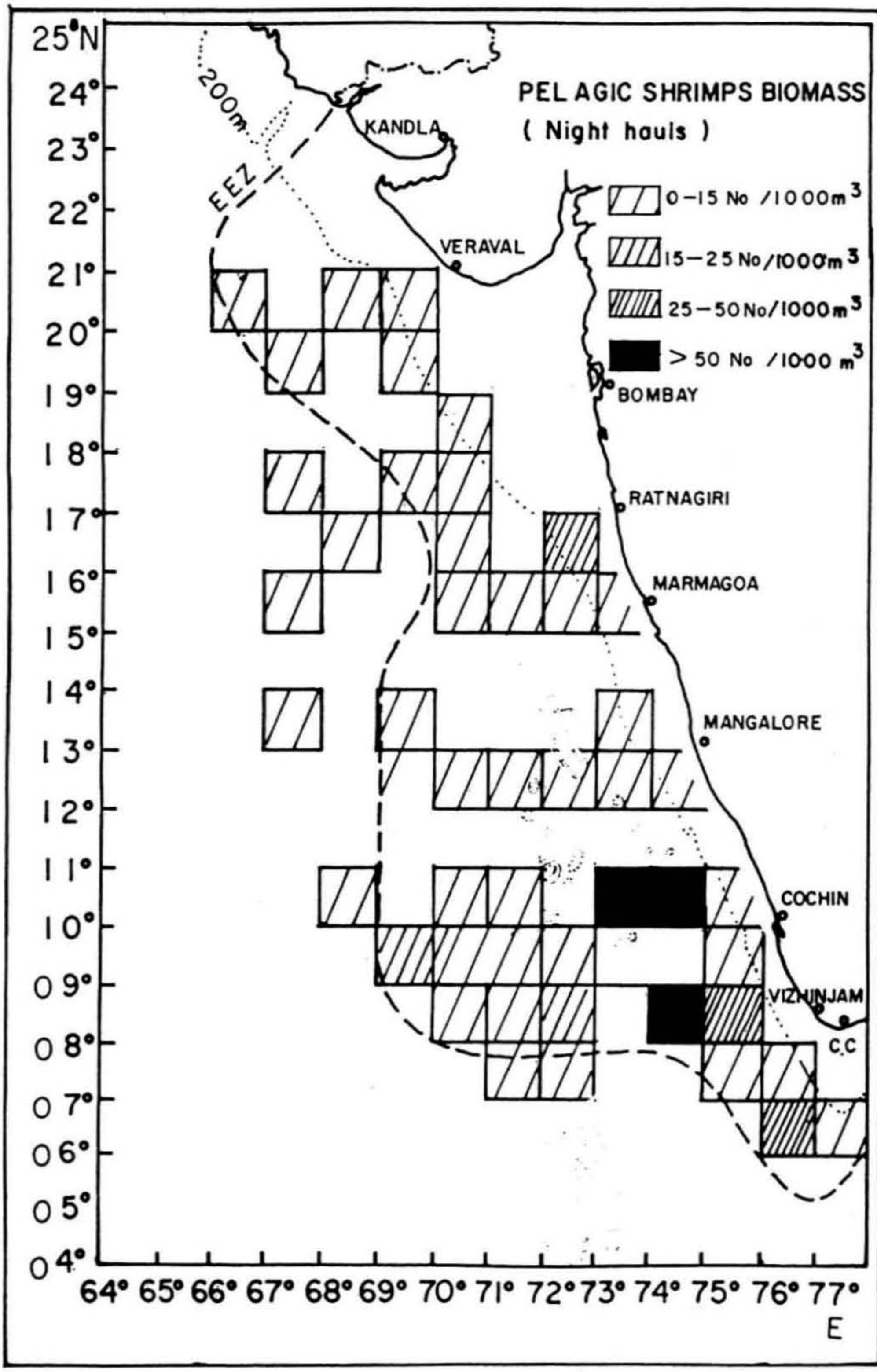

Figure 35. Geographical distribution and abundance (nos./1000 m^3) of pelagic shrimps from the night hauls of IKMT in the DSL of the west coast of India.

Vertical and horizontal distribution

From the vertical distribution studies (operational depthwise), it was found that the pelagic shrimps were abundant at depth ranges 51-200 m (777.22 nos./1000 m^3) and 0-50 m (645.36 nos./1000 m^3). The operational depth of above 300 m yielded only 124.34 nos./1000 m^3, whereas the operational depth of 200-300 m yielded about 98.47 nos./1000 m^3.

This shows that during night, pelagic shrimps were more concentrated in the upper strata (0-200 m) of the ocean. The other depth ranges 201-300 m and above 300 m had values 6.5 and 18.18 respectively. The day samplings yielded poor catches (Figure 36).

The horizontal distributional (station depthwise) analyses showed that the pelagic shrimps were more dense (1353 nos./1000 m^3) in the deep waters (1001-3000 m). The water above 201-1000 m recorded 185.1 nos./1000 m^3 and the shelf waters (100-200 m) yielded only 11.44 nos./1000 m^3. The sampling from the deep waters (3000 m) yielded 94. 96 nos./1000 m^3.

The results revealed that good catches were obtained from stations with depths ranging from1001 to 3000 m, with a catch rate of 1219 nos./1000 m^3 during night. Day catches were invariably poor (Figure 37).

Also the results showed that pelagic shrimps preferred continental slope waters with a depth range of 1001 to 3000 m at night and the depth of occurrence was found to be 0-200 m both during the postmonsoon and premonsoon seasons.

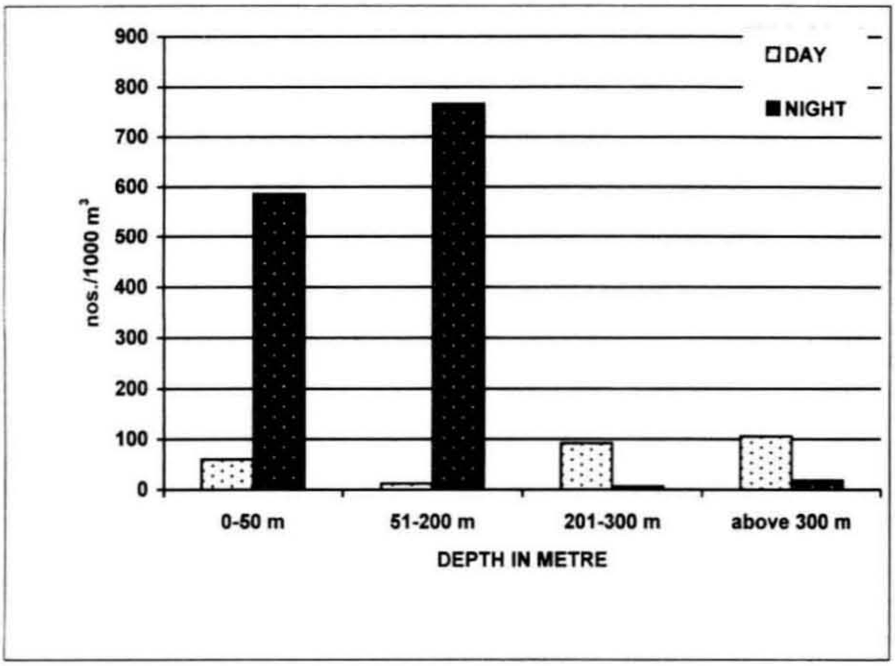

Figure 36. Day and Night variation in abundance (nos./1000 m^3) of pelagic shrimps (Vertical distribution)

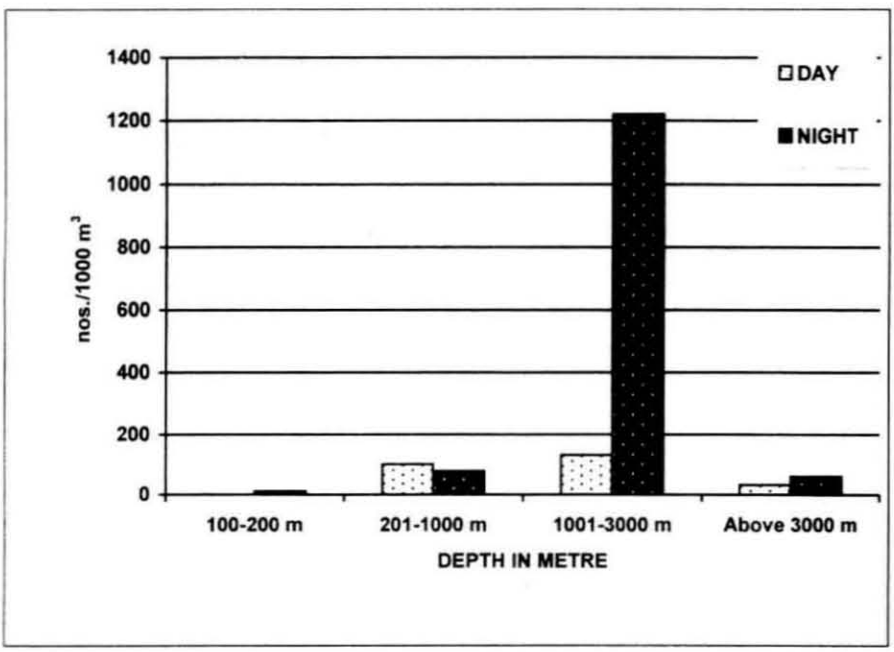

Figure 37. Day and Night variation in abundance (nos./1000 m^3) of pelagic shrimps (Horizontal distribution)

3. 3. 2 GEOGRAPHICAL DISTRIBUTION AND ABUNDANCE OF MAJOR FAMILIES OF PELAGIC SHRIMPS IN THE DSL

In the collections of IKMT, the pelagic shrimps of DSL along the west coast of India comprised 11 families. The familywise estimated biomass abundance (nos./1000 m^3) is presented in Table 2. It shows that the family Pasiphaeidae and Thalassocaridae recorded more than 10 nos./1000m^3. The next important families were Sergestidae, which formed 3.38 nos./1000m^3 and Luciferidae, (2.84 nos./1000 m^3). The other families such as Oplophoridae, Benthesicymidae, Nematocarcinididae, Pandalidae, Penaeidae, Solenoceridae and Stenopodidae were recorded in lesser quantities.

The familywise analysis also, indicated more catches during night. The day catches were dominated by families, Sergestidae (3 nos./1000m^3), Pasiphaeidae (2.5 nos./1000 m^3), Luciferidae (1.94 nos./1000 m^3) and Benthesicymidae (1.58 nos./1000 m^3). Other families present had biomass below 1 nos./1000 m^3. Families Pasiphaeidae (20.5 nos./1000 m^3), Thalassocaridae (20 nos./1000 m^3), Luciferidae (3.94) and Sergestidae (3.56 nos./1000 m^3) were dominant at night.

3. 3. 2. 1 FAMILY : PASIPHAEIDAE

Out of the11 families of pelagic shrimps, Pasiphaeidae formed the second most numerically abundant family in the DSL and it is located between latitude 07^0-21^0 N and longitude 67^0-76^0 E.

Distribution and abundance of Pasiphaeidae in various geographic areas of the EEZ is given in Figure 38. It was recorded from the entire west coast, from Cape Comorin to off Veraval. Maximum density was recorded at 10–73 degree squares (178 nos./1000 m^3) off Cochin from the night collections taken at 50 m depth during May.

Table 2. Familywise day and night distribution (nos./1000 m^3) of pelagic shrimps in the DSL

Sr.No	Families	Day nos./1000 m^3	Night nos./1000 m^3
1	Thalassocarididae	0.58	20
2	Pasiphaeidea	2.5	20.5
3	Sergestidae	3	3.56
4	Luciferidae	1.94	3.94
5	Benthecisymidae	1.58	1.59
6	Nematocarcinidae	0.05	3.8
7	Oplophoridae	0.6	1.49
8	Pandalidae	0.07	0.6
9	Solenoceridae	0	0.06
10	Stenopodidae	0.04	0
11	Penaeidae	0.03	0

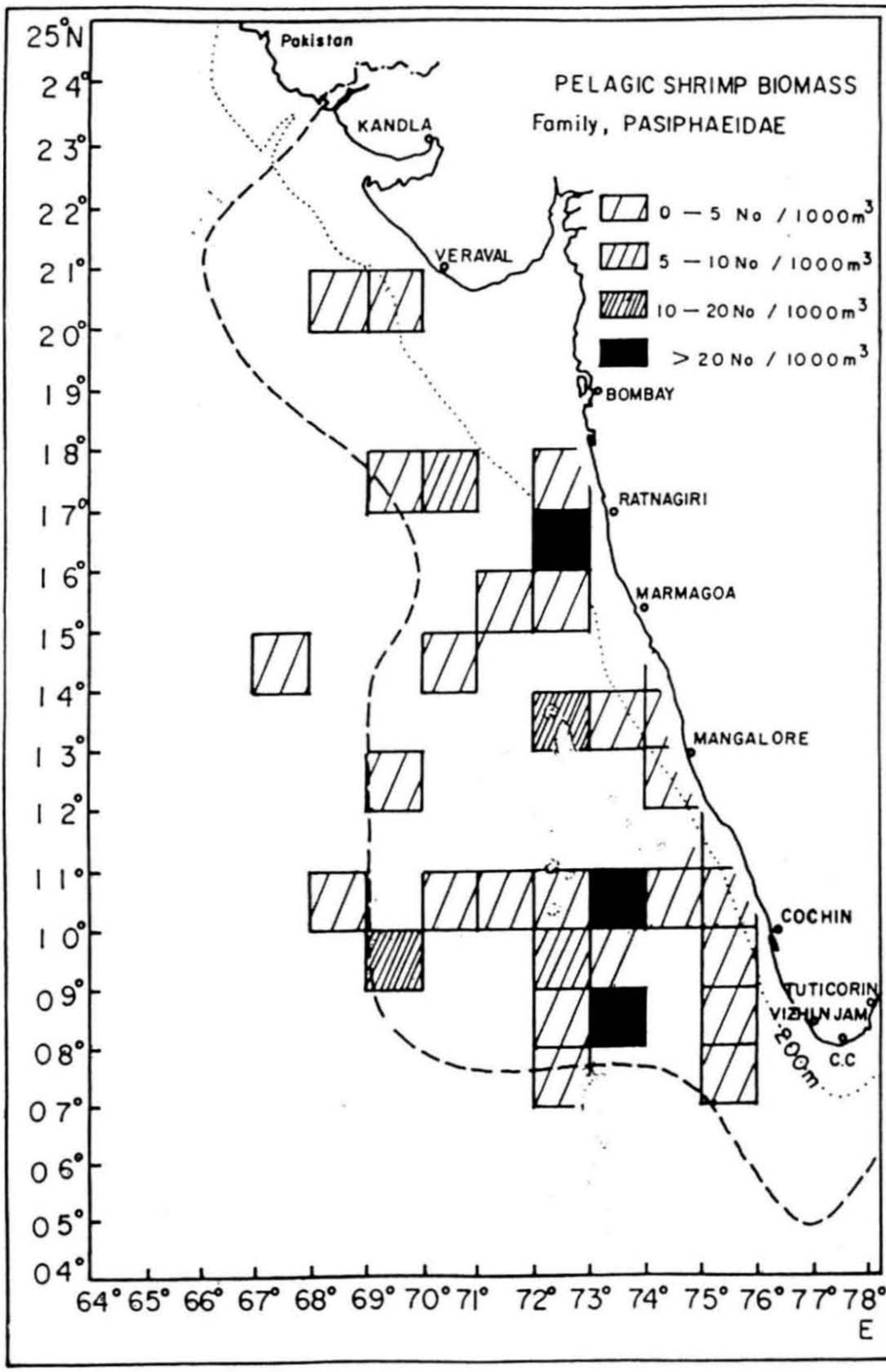

Figure 38. **Geographical distribution and abundance (nos./1000 m^3) of family Pasiphaeidea in the DSL along the west coast of India (day and night combined).**

Day and night variations in abundance

The night samples contained more density of shrimps belonging to family Pasiphaeidae compared to the day samples.

Day

Geographic abundance (nos./1000 m^3) of Pasiphaeidae in the DSL day hauls is given in Figure 39. Pockets of high-density biomass identified were at 08-73 degree squares (25.2 nos./1000 m^3) off Vizhinjam followed by 13-72 degree squares (10.6 nos./1000 m^3) off Mangalore and at 17–70 degree squares (13.4 nos./1000 m^3) off Ratnagiri.

Night

Rich concentrations of pelagic shrimps belonging to Pasiphaeidae were observed at 10–73 degree squares (178 nos./1000 m^3) off Cochin, 16–72 degree squares (30.2 nos./1000 m^3) off south Ratanagiri (Figure 40).

Vertical and horizontal distribution

The family Pasiphaeidae was more abundant in the depth (operational) range of 0-50 m (40.21 nos./1000 m^3). In the depth range of 50- 200 m a catch rate of 15.34 nos./1000 m^3 was obtained. Lesser quantities were recorded in other depths.

During night, the family Pasiphaeidae was more abundant in the depth range of 0-50 m (38.73 nos./1000 m^3) followed by 50-200 m (14.34 nos./1000 m^3). Catches were poor from depths above 200 m. Lesser quantities were (0.96 nos./1000 m^3 to 5.62 nos./1000 m^3) obtained from all the depths during day (Figure 41).

Maximum populations of Pasiphaeidae were recorded from (station depthwise) stations with depth range of 1500-2000 m (60.02 nos./1000 m^3). Next abundant collections were made from waters above 2500 – 3000 m (13.77 nos./1000 m^3).

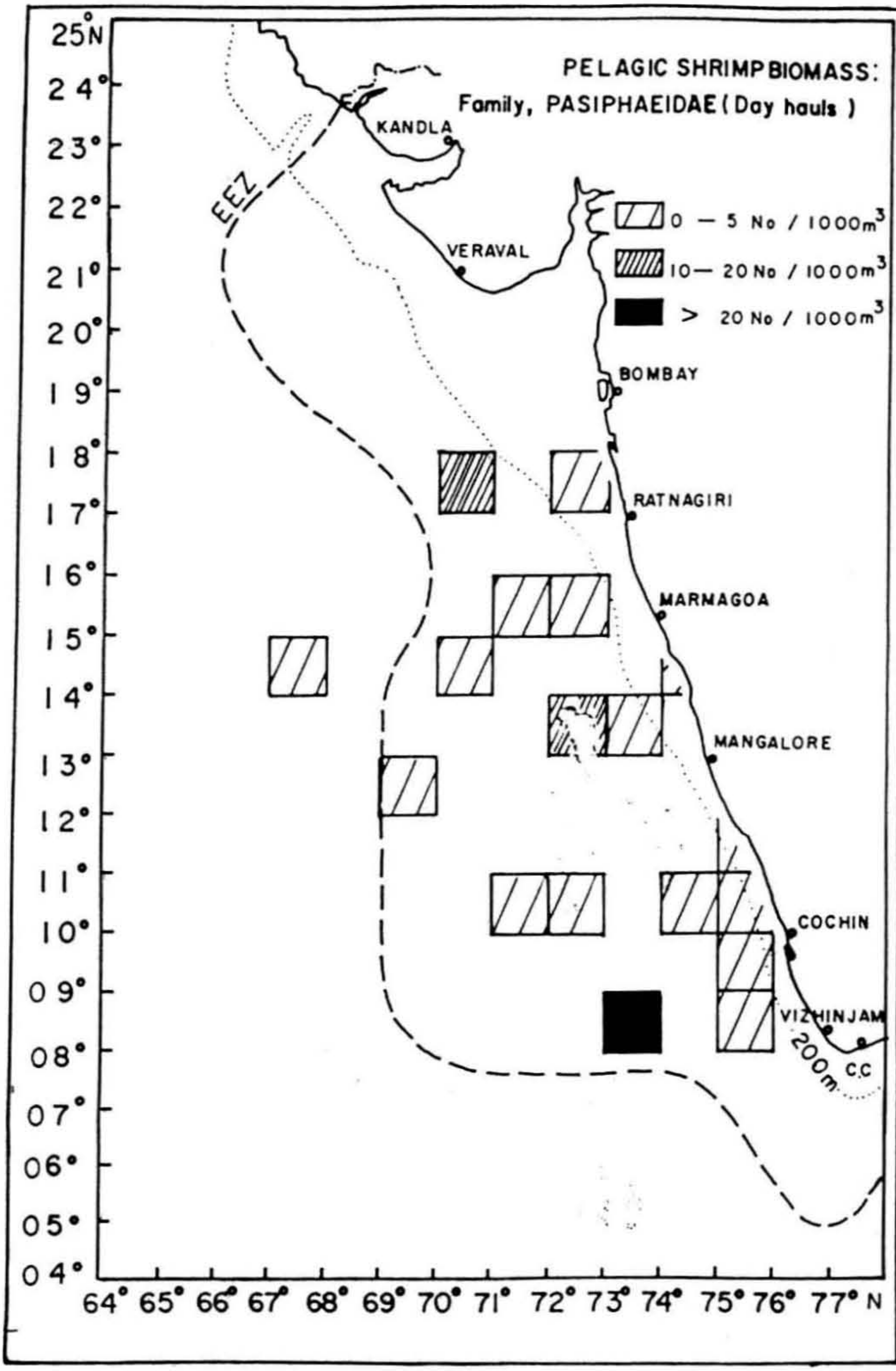

Figure 39. Geographical distribution and abundance (nos./1000 m^3) of family Pasiphaeidea from the day hauls in the DSL along the west coast of India.

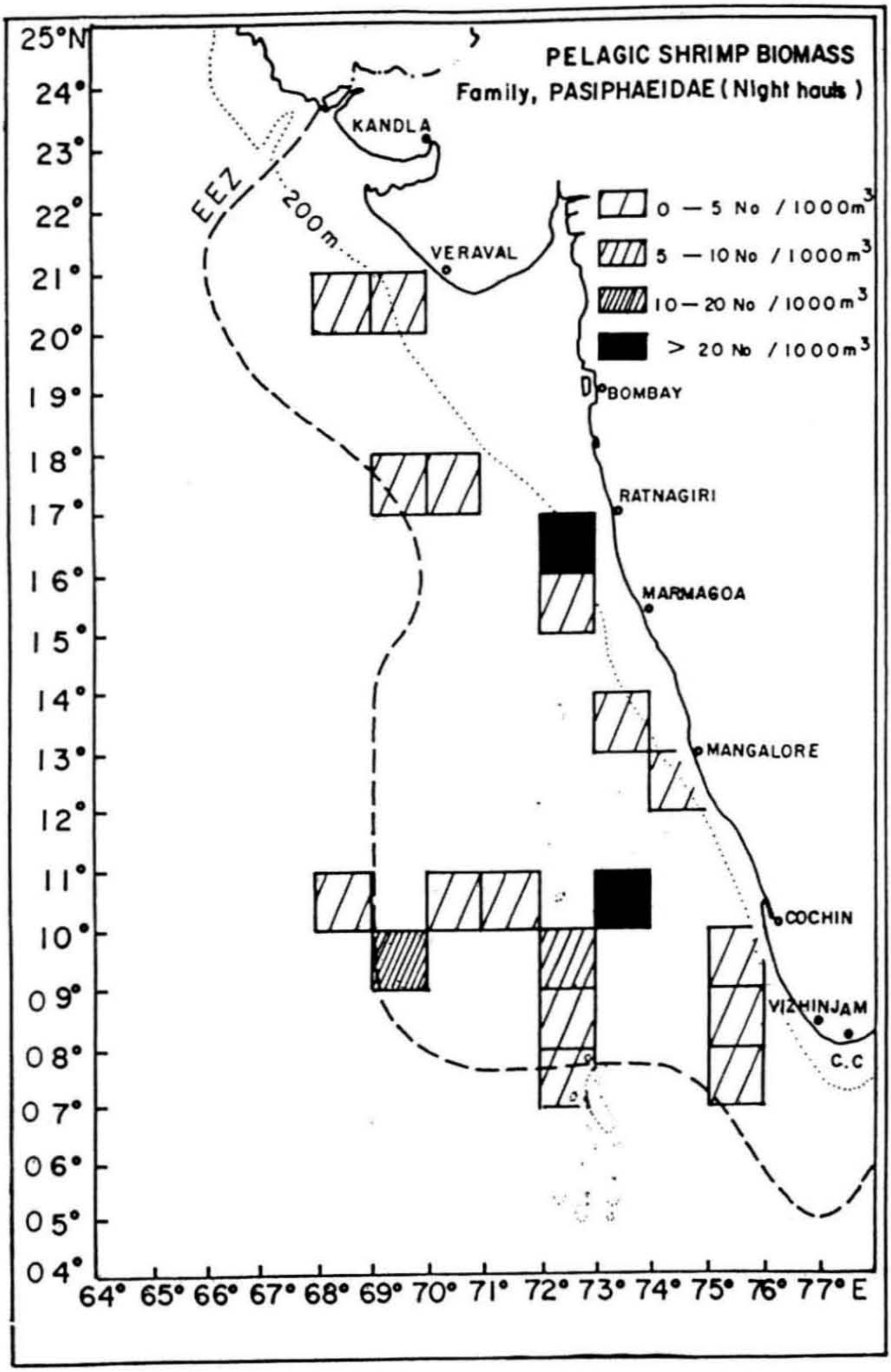

Figure 40. Geographical distribution and abundance (nos./1000 m^3) of family Pasiphaeidea from the night hauls in the DSL along the west coast of India.

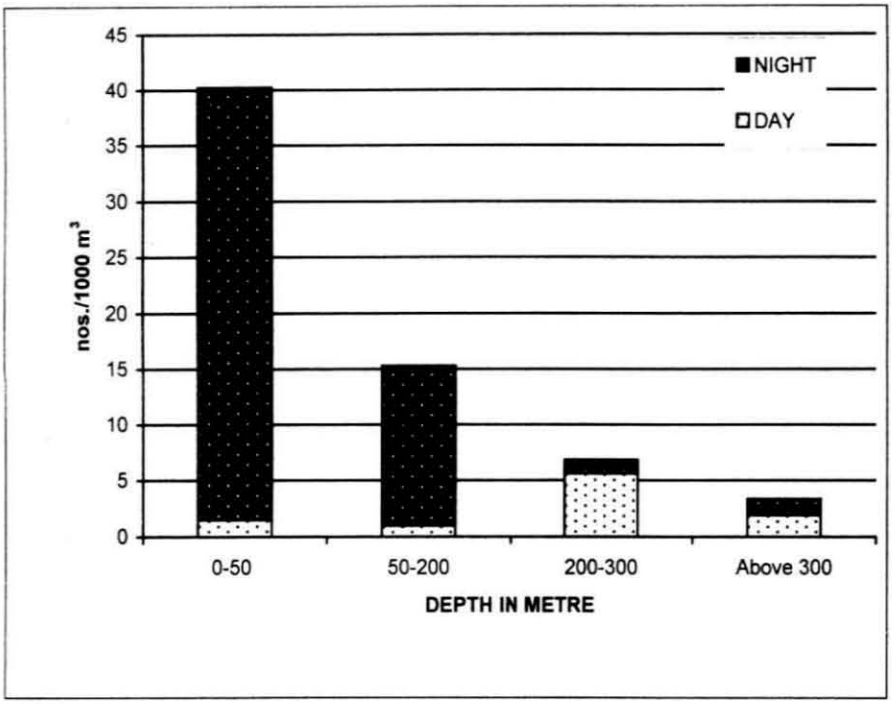

Figure 41. Day and night variation in abundance (nos./1000 m^3) of family Pasiphaeidae (Vertical distribution)

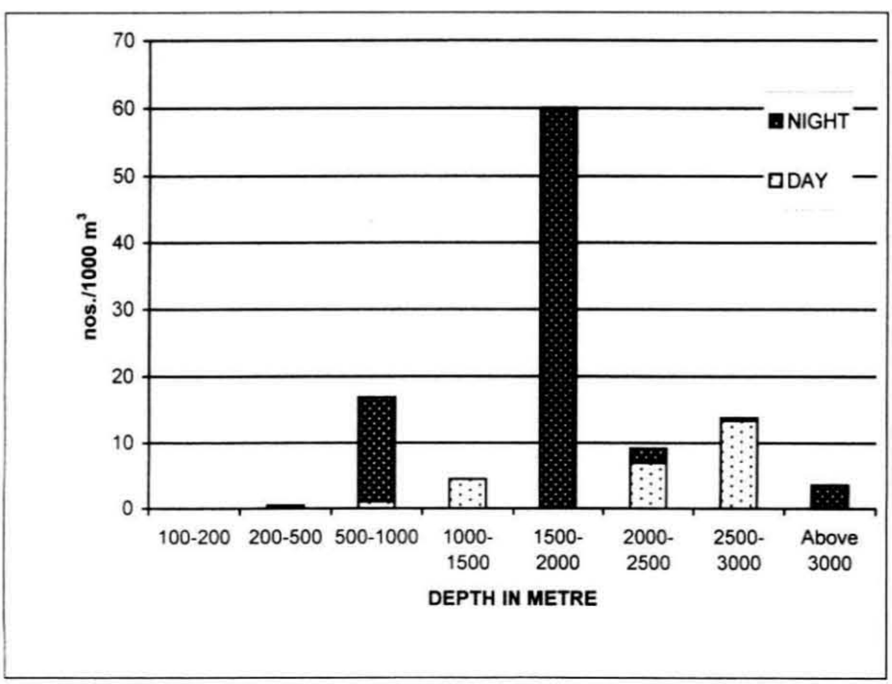

Figure 42. Day and night variation in abundance (nos./1000 m^3) of family Pasiphaeidae (Horizontal distribution)

Maximum catch of 59.95 nos./1000 m^3 was recorded from waters above 1500-2000 m during night. Waters above 500-1000 m yielded comparatively good catches (15.81 nos./1000 m^3). Poor catches of 0.26 nos./1000 m^3 to 3.48 nos./1000 m^3 were obtained from other depths. During day dense catches were obtained from the 2500 – 3000 m depth (13.39 nos./1000 m^3). The other depths yielded only 0.07 – 7 nos./1000 m^3/ (Figure 42).

3. 3. 2. 2 FAMILY: THALASSOCARIDIDAE

The family Thalassocarididae is the first numerically dominant group among pelagic shrimps of the DSL. It contributed about 39.6% (14.5 nos./1000 m^3) to the total pelagic shrimp biomass. It was recorded from southwest coast only. This family is available between 07^0-14^0 N and 67^0-77^0 E. The maximum biomass was recorded at 08–74 degree squares (153 nos./1000 m^3) followed by 08–75 degree squares (28 nos./1000 m^3) off Vizhinjam and 10 – 73 degree squares (16.6 nos./1000 m^3) off Cochin (Figure 43).

Because of less number of stations, the day and night abundance were not plotted.

Day

The maximum biomass was observed at 09–75 degree squares (2.5 nos./1000 m^3) off south Cochin during day.

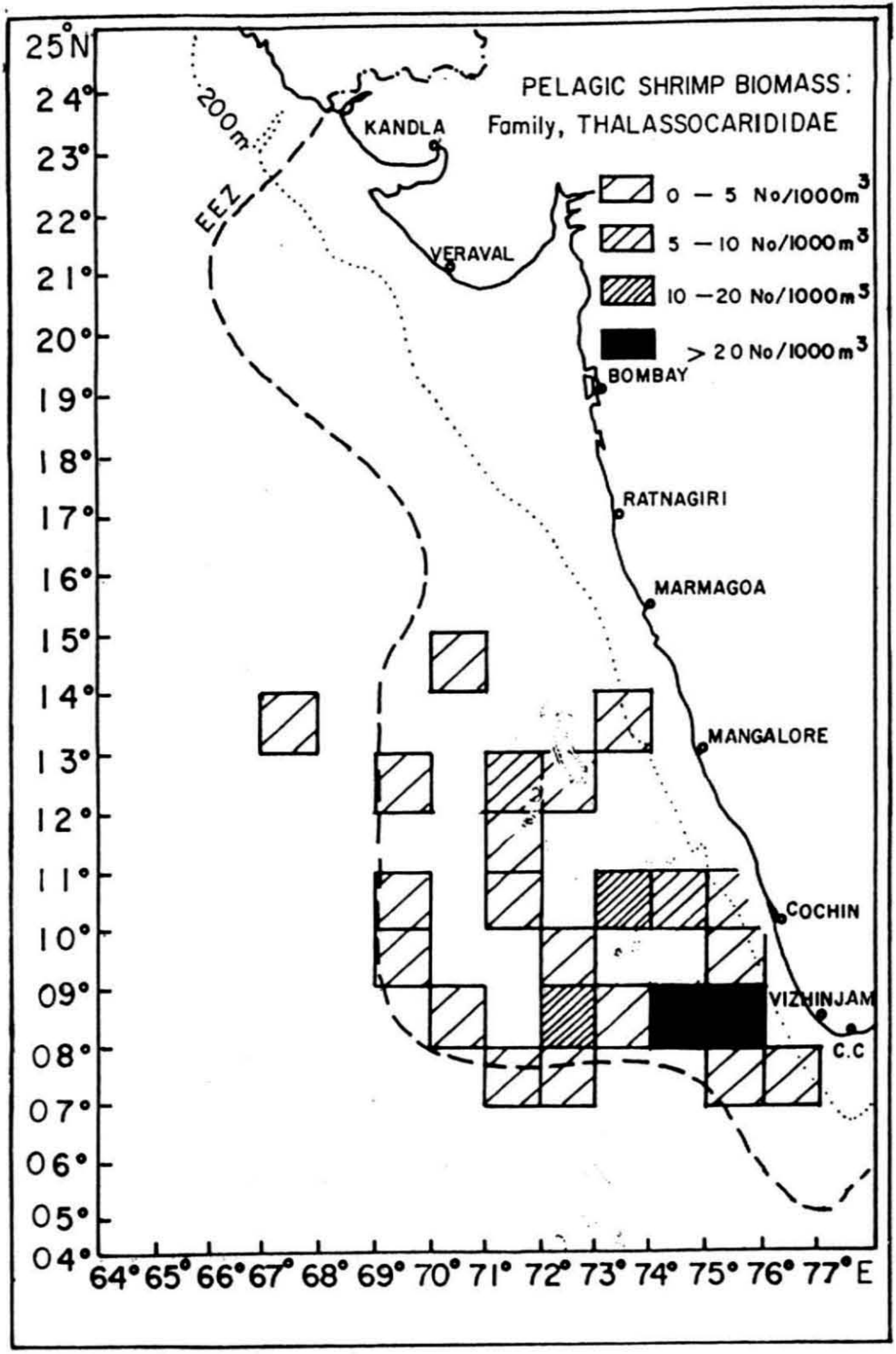

Figure 43. Geographical distribution and abundance (nos./1000 m³) of family Thalassocarididae in the DSL along the west coast of India (day and night combined).

Night

High biomass values were recorded at 08–74 degree squares (153 nos./1000 m^3), followed by 08–75 degree squares (28 nos./1000 m^3) off Vizhinjam and 10 - 73 degree squares (16.6 nos./1000 m^3) off Cochin.

Vertical and horizontal distribution

The vertical distribution analysis showed that the IKMT operated at the depth of 50-200 m yielded maximum catch (26.72 nos./1000 m^3) of Thalassocarididae. The next productive depth was 0-50 m (14.38 nos./1000 m^3). Above 200 m depth, the catch was poor.

During night, this family was occupying depths of 50-200 m (26.63 nos./1000 m^3), and 0-50 m (14.38 nos./1000 m^3). During day, catches were very low and the values ranged from 0.09 nos./1000 m^3/ to 0.78 nos./1000 m^3. This family was available only up to 400 m of IKMT operation (Figure 44).

The horizontal distribution analysis showed that this family was mostly available in the slope waters of 2500 – 3000 m depth (92.87 nos./1000 m^3). Smaller quantities were obtained from waters with depth of 1500-2000 m (10.14 nos./1000 m^3) and 2000 –2500 m (5.26 nos./1000 m^3).

During night, this family was densely populated at waters above 2500- 3000 m (91.39 nos./1000 m^3), and other depth ranges yielded a catch of 0.18 – 10 nos./1000 m^3. During day the catch was almost negligible (Figure 45).

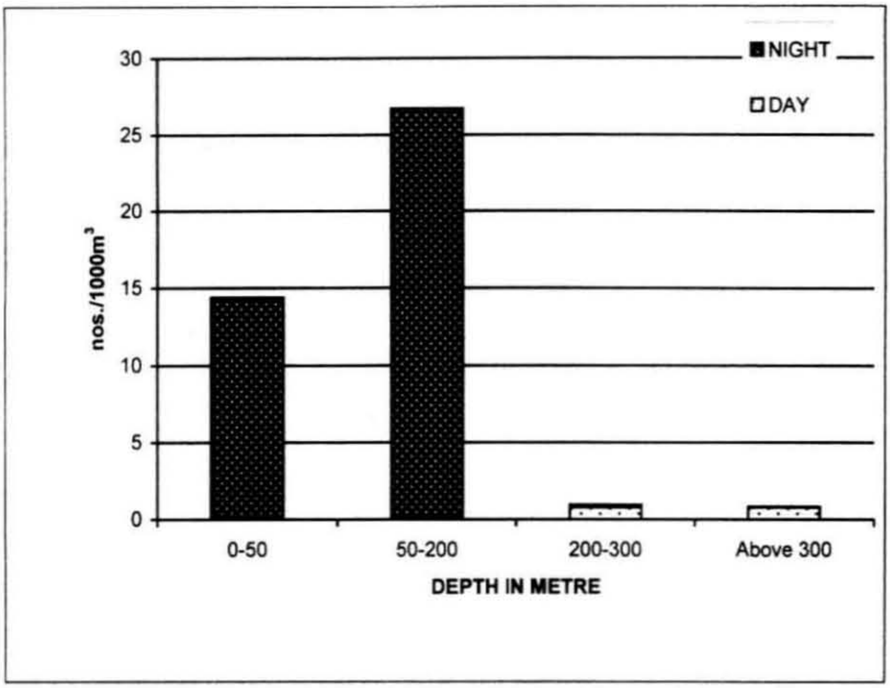

Figure 44. Day and night variation in abundance(nos./1000 m^3) of family Thalassocarididae (Vertical distribution)

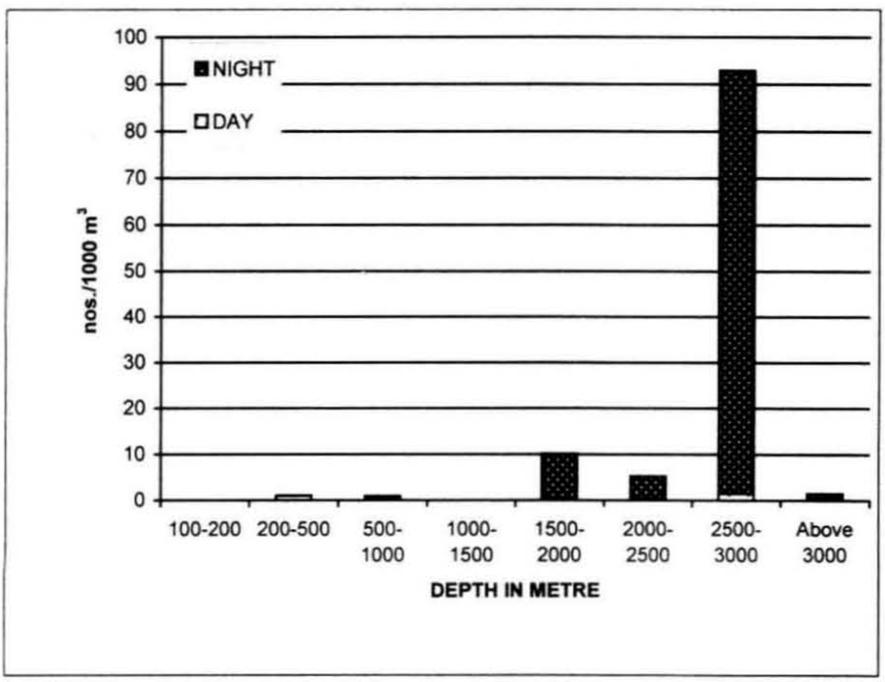

Figure 45.Day and night variation in abundance (nos./1000 m^3) of family Thalassocarididae (Horizontal distribution).

3. 3. 2. 3 FAMILY: SERGESTIDAE

Family, Sergestidae formed one of the major components of the pelagic shrimp biomass of the DSL, during day and night hauls with remarkable dominance in night hauls. It was available between 06^0-21^0 N and 66^0-77^0 E.

Family, Sergestidae enjoys wide distribution and occupies most parts of the near shore, off shore and oceanic regions (Figure 46). The maximum biomass (average for 1^0 squares) was recorded at 06-76 degree squares (24 nos./1000 m^3) off south Cape Comorin.

Day and night variations

Overall, the night sample values were higher than the day sample values.

Day

In day observations, high values of biomass were present at different geographic locations with maximum values at 10–73 degree squares (24.3 nos./1000 m^3) off Cochin; followed by 13–72 degree squares off Mangalore (9.9 nos./1000 m^3), 07–72 degree squares (6.8 nos./1000 m^3) off Cape Comorin and 06 - 76 degree squares (5.5 nos./1000 m^3) (Figure 47).

Night

Night observations showed, high-densities at 06–76 degree squares (43 nos./1000 m^3) off south Cape Comorin followed by 12–73 degree squares (13.9 nos./1000 m^3) off Mangalore, 10–74 degree squares (13.4 nos./1000 m^3) off north Cochin, and 08–75 degree squares (13 nos./1000 m^3) off Vizhinjam. Fairly high values of biomass were noticed in almost all the night stations (Figure 48).

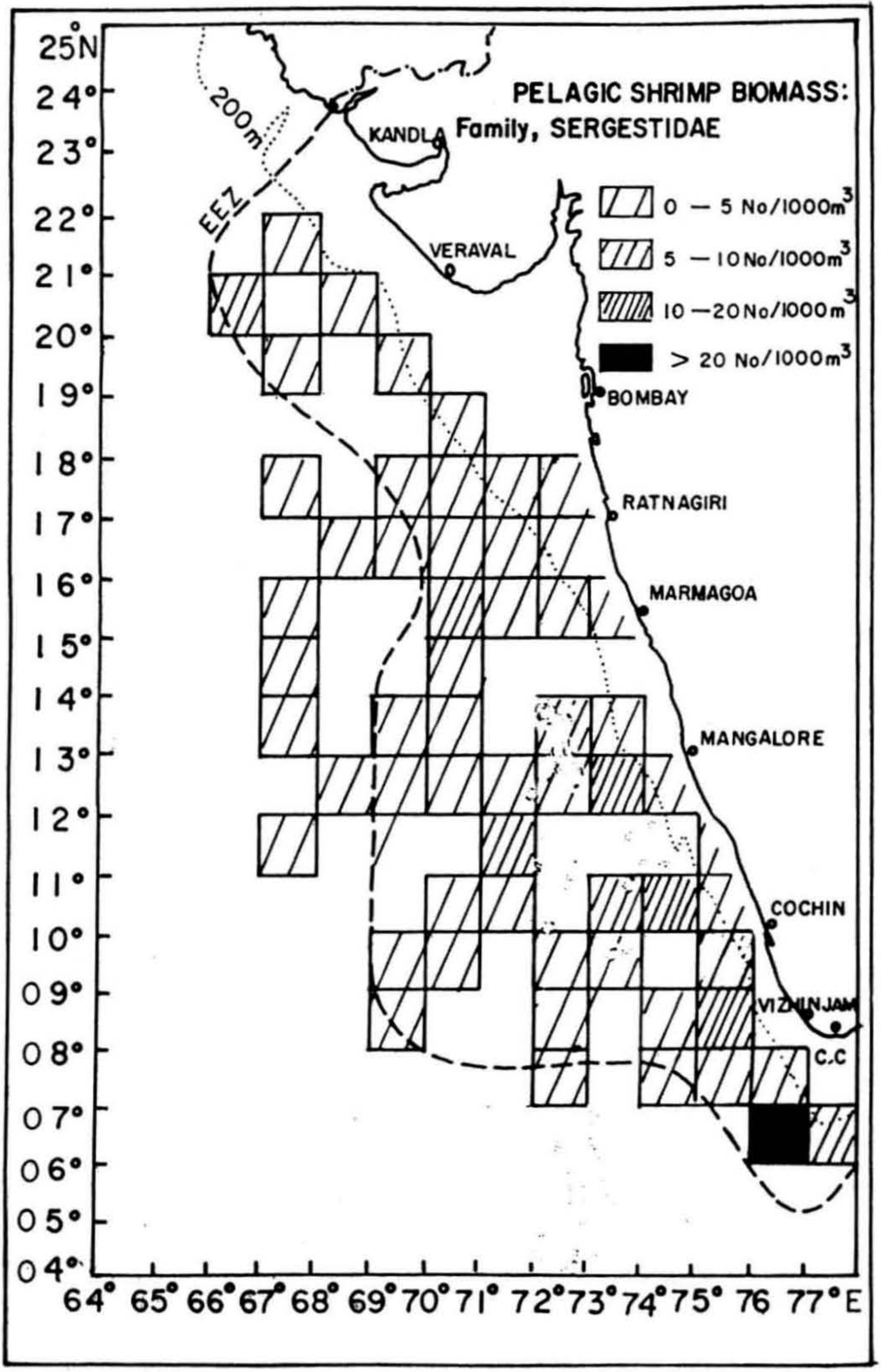

Figure 46. Geographical distribution and abundance (nos./1000 m^3) of family Sergestidae in the DSL along the west coast of India (day and night combined).

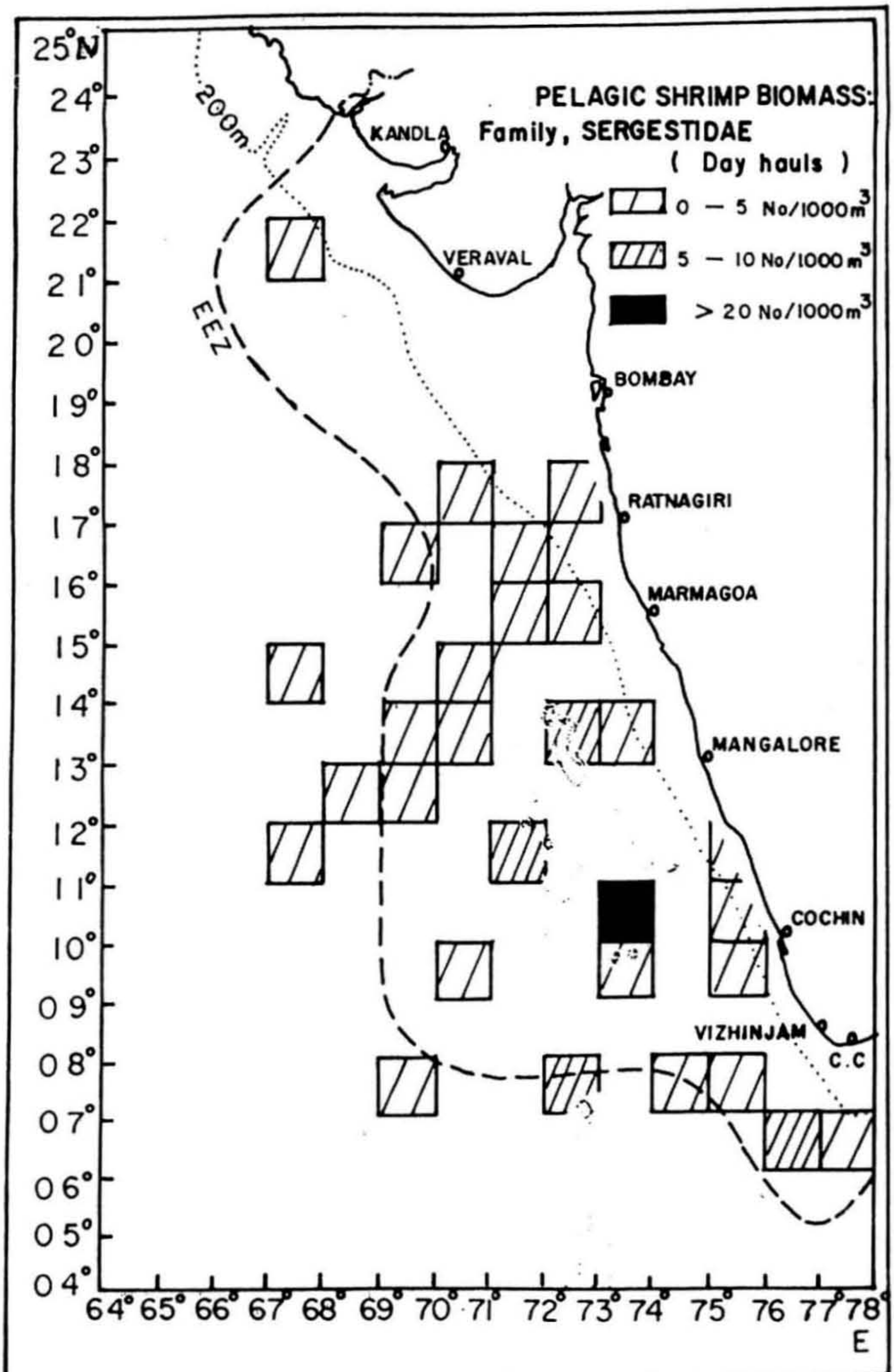

Figure 47. Geographical distribution and abundance (nos./1000 m^3) of family Sergestidae from the day hauls in the DSL along the west coast of India.

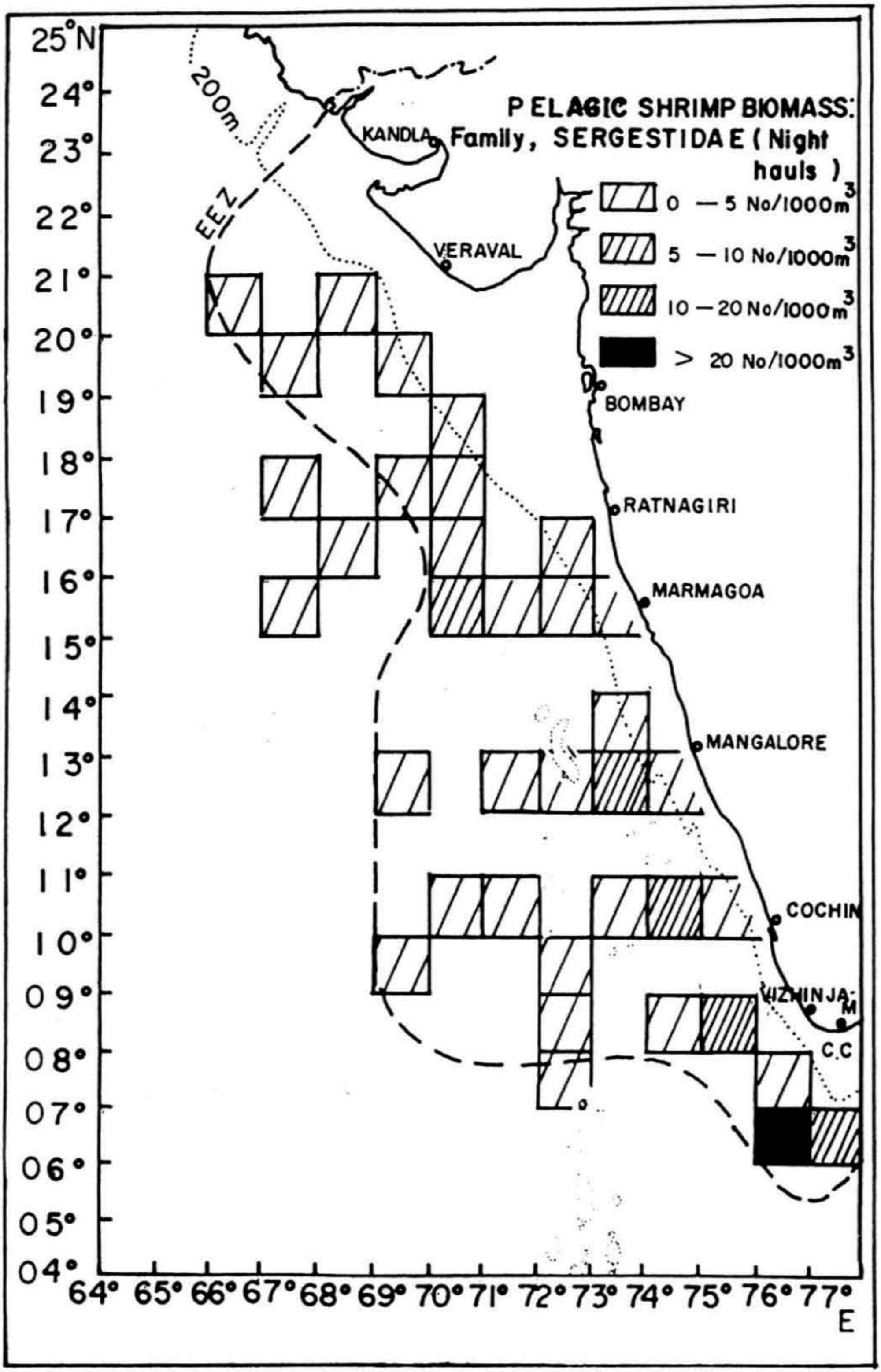

Figure 48. Geographical distribution and abundance (nos./1000 m³) of family Sergestidae from the night hauls in the DSL along the west coast of India

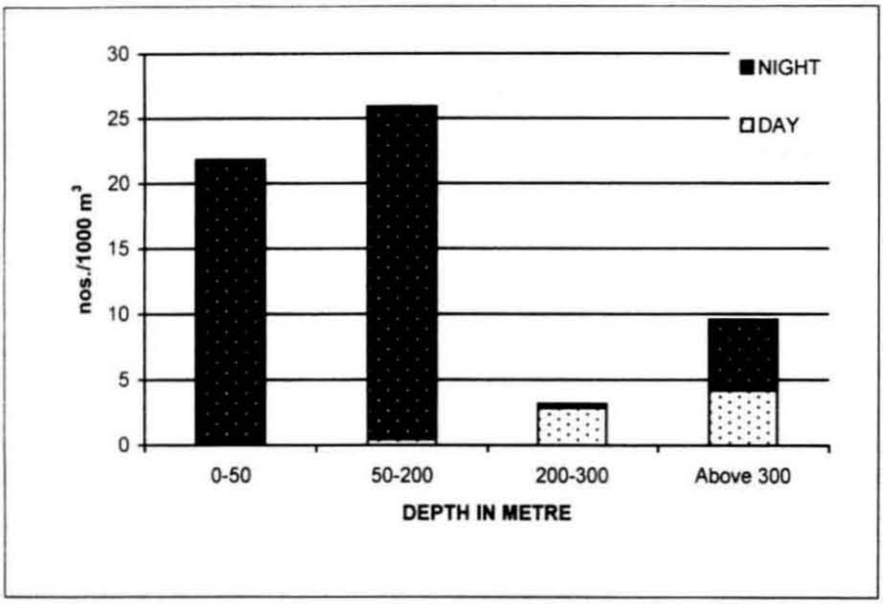

Figure 49. Day and night variation in abundance (nos./1000 m^3) of family Sergestidae (Vertical distribution)

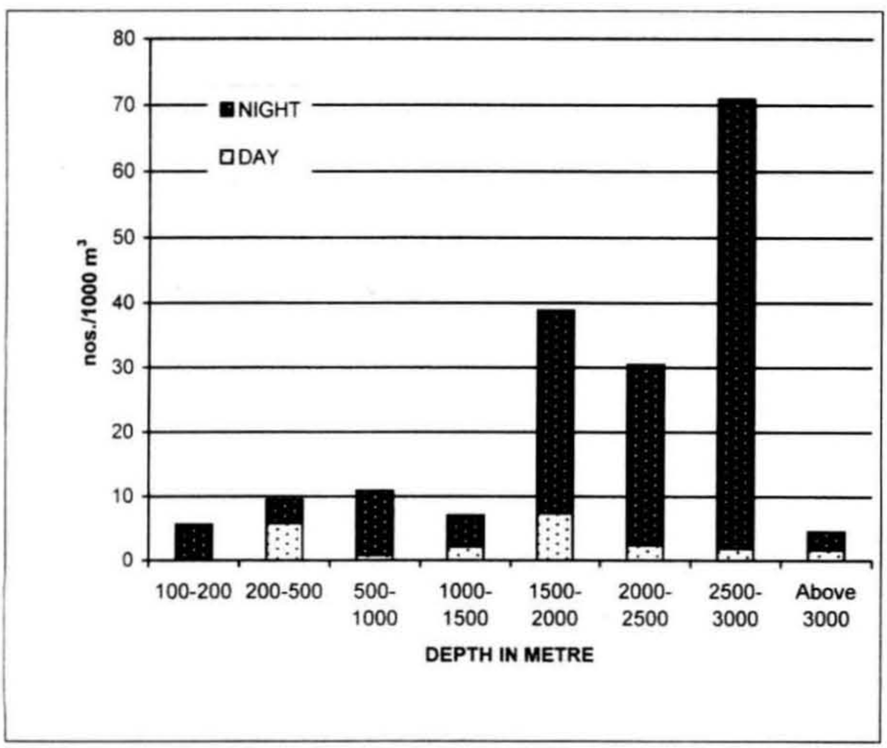

Figure 50. Day and night variation in abundance (nos./1000 m^3) of family Sergestidae (Horizontal distribution).

Vertical and horizontal distribution

Generally the maximum population of Sergestidae was observed at the depth range of 0-200 m & 50- 200 m, (26.79 nos./1000 m^3 & 21.33 nos./1000 m^3).

More or less similar catch trend was observed in the IKMT night hauls. Day catches yielded only 0.07 – 4.19 nos./1000 m^3/ from 200-300 m and above 300. This family occurred at 10-750 m depth (Figure 49).

In the horizontal distribution studies, it is seen that the highest catch (70.89 nos./1000 m^3) was recorded in the depth range of 2500-3000 m. Next higher abundance was located in the depth ranges 1500-2000 m (38.81 nos./1000 m^3) and 2000-2500 m (30.42 nos./1000 m^3). Other depth ranges were poorly represented. Similar pattern was found during night. The day catches were invariably poor (Figure 50).

3. 3. 2. 4 FAMILY : OPLOPHORIDAE

Another important group of pelagic shrimps is the family, Oplophoridae. This family formed about 2.67% (0.94 nos./1000 m^3)of total pelagic shrimp biomass and is found to occur between 06^0 -18^0N and 67^0 -76^0E.

Comparatively more samples of family Oplophoridae were obtained from the southwest coast. Along the northwest coast it was recorded from only one area i.e 18 - 68 degree squares with a catch rate of 0.18 nos./1000 m^3 off Mumbai. In the south, this group occurred in all the areas from off Cape Comorin to off Mangalore. The maximum biomass was recorded at 08 – 72 degree squares (5.4 nos./1000 m^3) off Vizhinjam (Figure 51).

Because of less number of stations, the day and night abundances were not plotted.

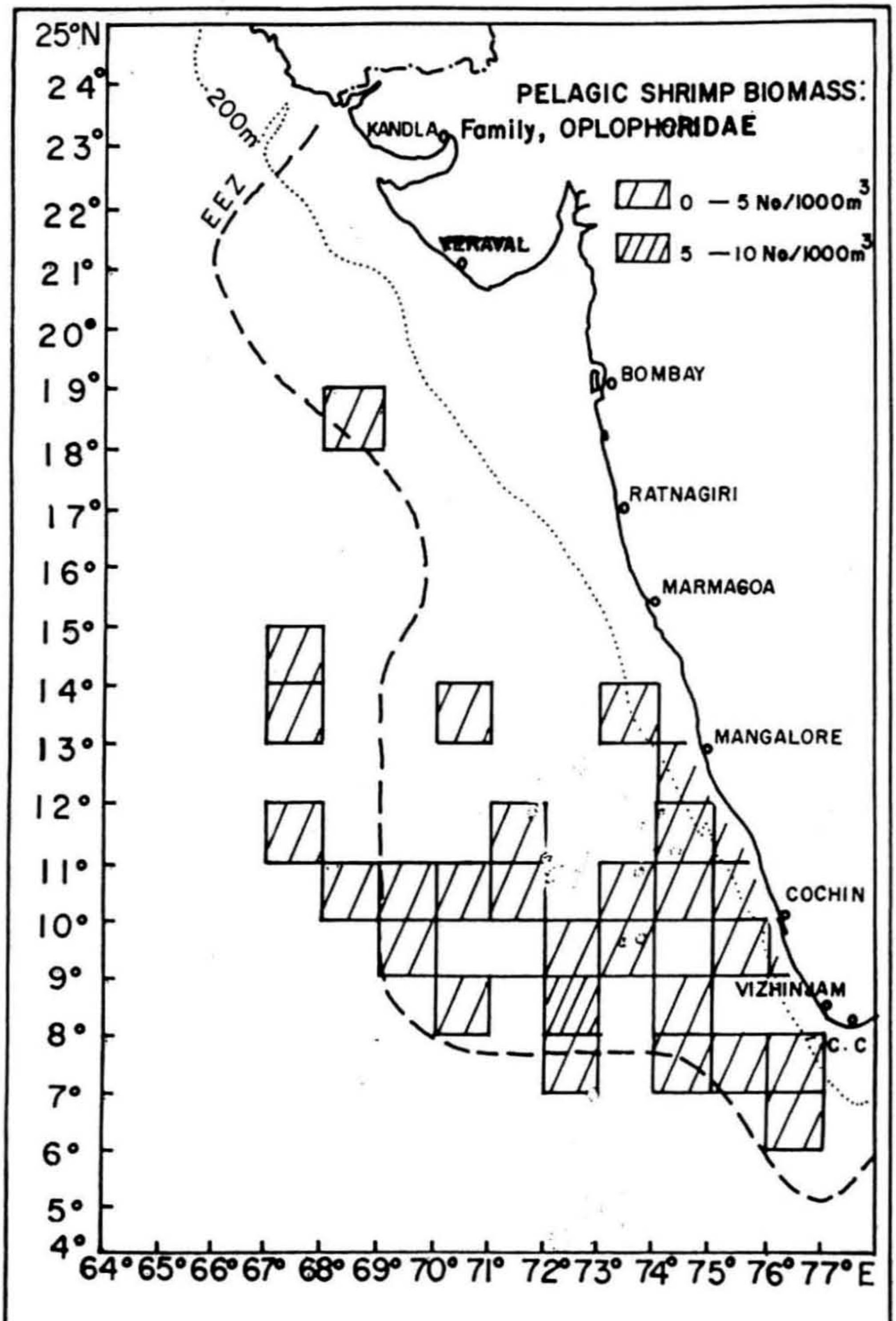

Figure 51. Geographical distribution and abundance (nos./1000 m^3) of family Oplophoridae in the DSL along the west coast of India (day and night combined).

Day

The day sample contained less quantities of Oplophoridae (0.6 nos./1000 m^3) in total biomass. The maximum biomass was recorded at 11–74 degree squares (2 nos./1000 m^3) off Mangalore.

Night

The night sample contained comparatively more quantities of Oplophoridae (1.49 nos./1000 m^3). The maximum biomass located at 08–72 degree squares (5.4 nos./1000 m^3) off Vizhinjam.

Vertical and horizontal distributions

The catch was restricted to the depth ranging from 50 to > 750 m (Figure 52). The depth ranges 50-200 m and > 300 m yielded a catch of 2.37 and 2.35 nos./1000 m^3 respectively. The catch was abundant at night and day catches were poor.

The family was most populated in the waters above 1500-2000 m (5.76 nos./1000 m^3). The depth range 200-1500 m yielded 1.63 to 2.99 nos./1000 m^3. During night it was present only in the three depth ranges and the maximum was at 1500 –2000 m (5.4 nos./1000 m^3) followed by 500-1000 m (2.6 nos./1000 m^3). It was interesting to note that the catch was available from all the waters except with depth of 100-200 m (Figure 53).

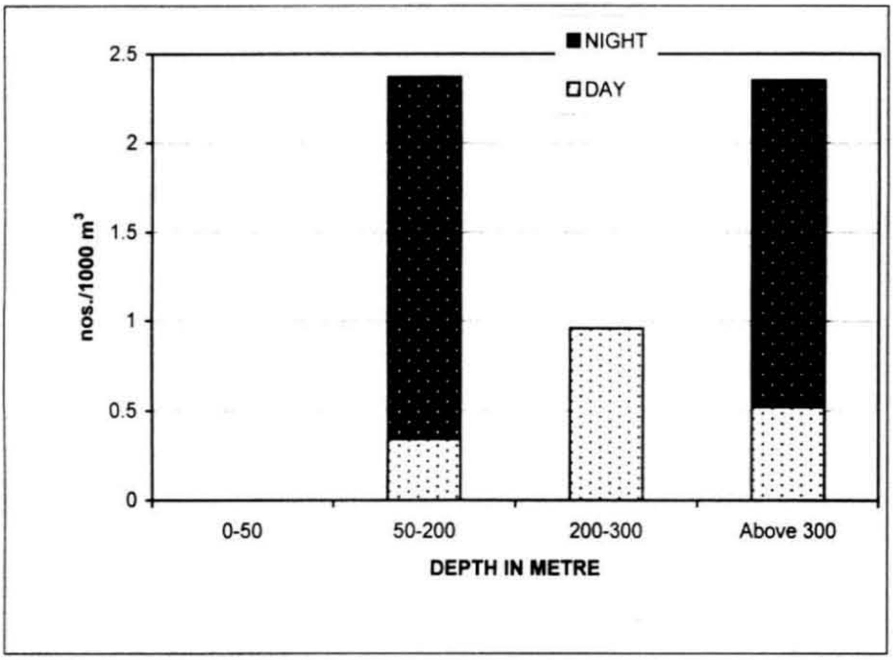

Figure 52. Day and night variation in abundance (nos./1000 m^3) of family Oplophoridae (Vertical distribution).

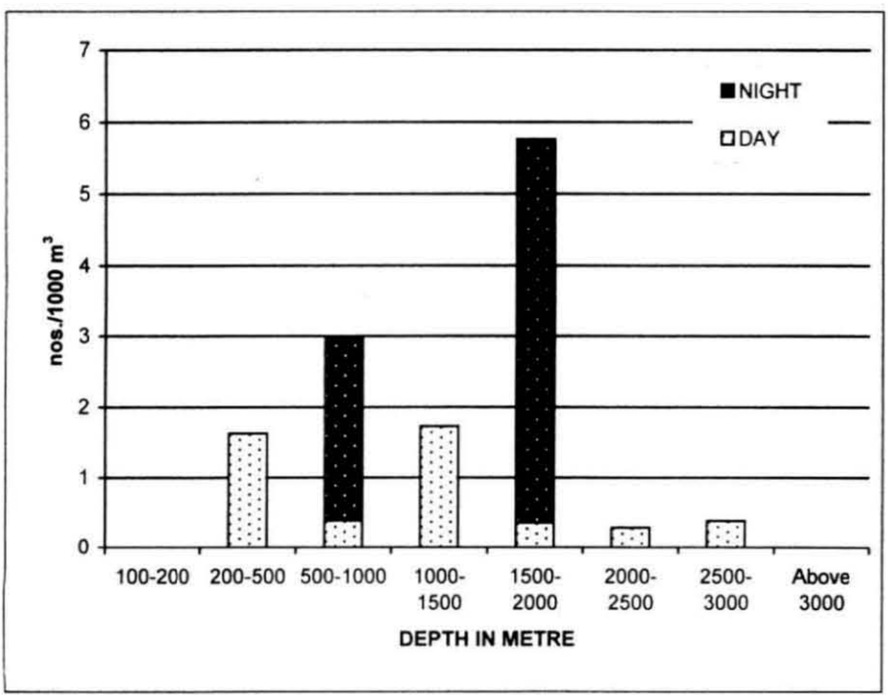

Figure 53. Day and night variation in abundance (nos./1000 m^3) of family Oplophoridae (Horizontal distribution).

3.4 ESTIMATED BIOMASS OF PELAGIC SHRIMPS IN THE DSL

Though pelagic shrimps are present throughout the operational depth range (10-750 m), it was found that the depth preferred by these forms during different seasons, time, position, life stages etc. do change to a considerable extent. In order to study the variation in the vertical distribution of pelagic shrimps, data was analyzed for 4 depth zones, namely 0-50 m, 50-200 m, 200 –300 m, and > 300 m. The abundance of pelagic shrimps in the different depth zones has been studied on the basis of the total biomass in tonnes (1° squares).

The result shows that the estimated average pelagic shrimp biomass was 655 t from a total of 123 IKMT stations during May 1998 – December 2000.

3. 4 .1 OPERATIONAL DEPTH ESTIMATED BIOMASS

The vertical distribution of shrimps, as well as that of other crustaceans in general, is principally modified by food supply, light penetration and temperature, although other physical variables such as salinity, dissolved oxygen and hydrostatic pressure have varying effect on it. Presumably, some of these variables interact as part of a complex of environmental factors (Omori, 1974).

Biomass estimation

The biomass estimation summarizes (above 300 m) that the catch from deeper depth was more when compared to the catch from lower depths of (0-300 m). The vertical distribution analysis of pelagic shrimps shows that they are more abundant (54.93%) at depths above 300 m and the minimum values were observed at 50-200 m (10.98 %) depth range. About 77% of the catches were obtained from depth ranges of

200-300 and above 300 m combined. Though these pelagic shrimps were present at all the depths range (0-50 m, 50-200 m, 200-300 m and above 300 m), the biomass was found to be increasing with increase in depths (Figure 54).

Diurnal variation

The pelagic shrimps occur mainly at depths of 200 m and above (99.23%), with 58% (1287 t) recorded from above 300 m depth and 41.13 % (911 t) recorded at 200-300 m depth during day. Very low catches, about 0.63% (14 t) and 0.14% (3 t) recorded from 0-50 m and 50-200 m respectively.

At night, the amplitude of catches was high at depth range above 300 m (52%) and followed by 0-50 m (22.45%) and 50–200 m (21.18%), low catches were obtained from 200-300 m (4.37%). This shows that the part of pelagic shrimps come up to surface waters at night, and found to occupy depths upto 200 m depth (Figure 55).

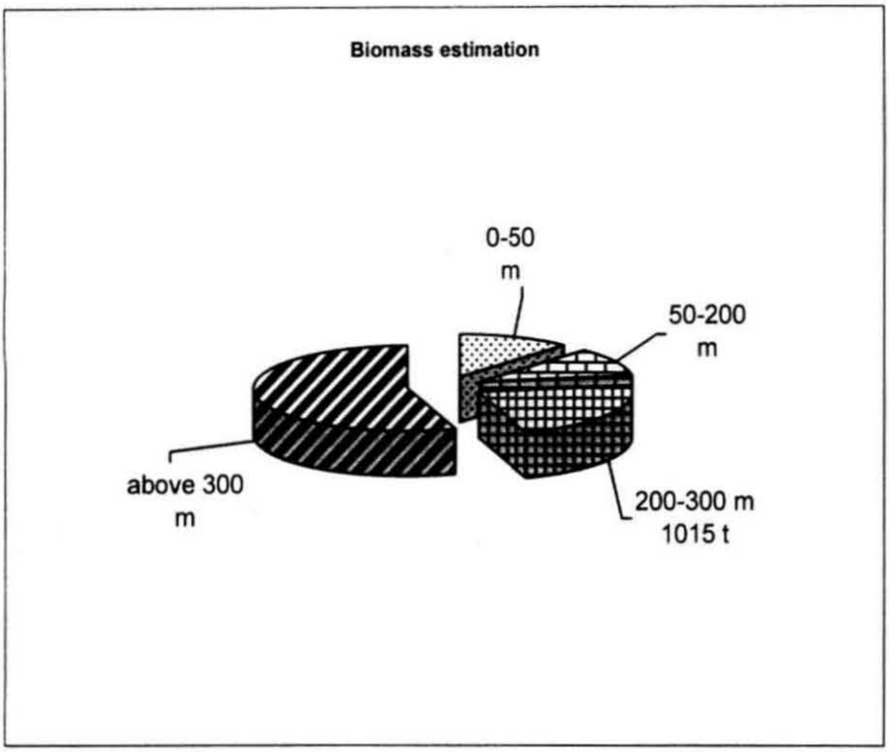

Figure 54. Depthwise biomass (t) estimation

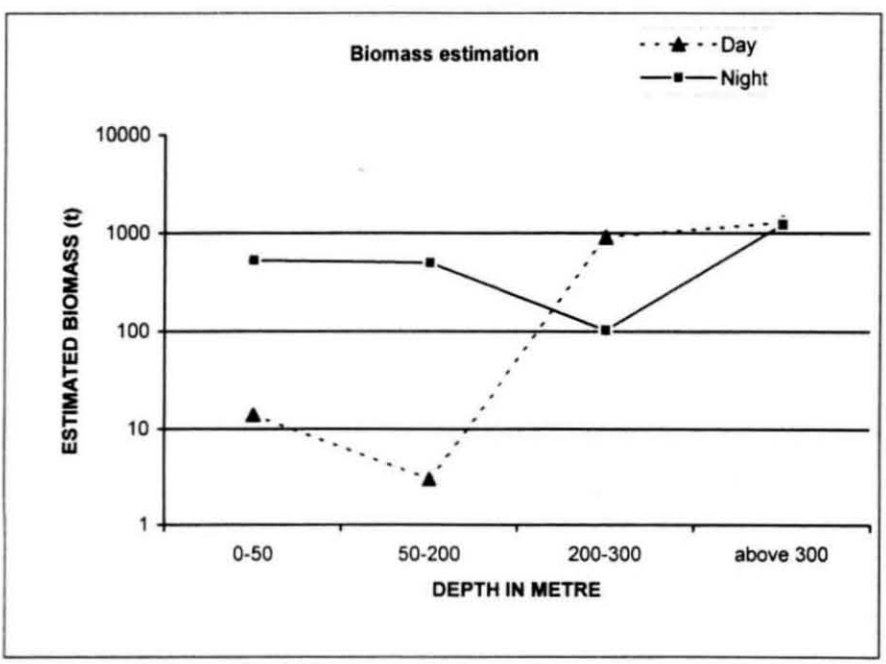

Figure 55. Depthwise biomass estimation (t) in relation to day and night hauls

3. 4. 2 STATION DEPTHWISE ESTIMATED BIOMASS

In order to study the variation in the horizontal distribution of pelagic shrimps, the depth ranges selected were 100-200 m, 200-500 m, 500-1000 m, 1000-1500 m, 1500-2000 m, 2000-2500 m, 2500-3000 m and above 3000 m.

Biomass estimation

Maximum biomass of 1388 t (27%) was obtained from stations with depth range of 2500-3000 m followed by 761 t (15.12%) from 1500-2000 m depth range. From stations with depths 1000 –1500 m and 2000- 2500 m, the values obtained were 699 t (13.88%) and 696 t (13.81%) respectively. Very low catch was recorded from the shelf waters (Figure 56).

Diurnal variation

During day, the pelagic shrimp catch was fairly good in waters with depth range of 1500-2000 m (30.35%) and 1000-1500 m (18.14%) and the values were 1,939 t and 1,159 t respectively. Comparatively higher catches were obtained from stations with depth 2500-3000 m (13.60%), 200-500m (13.35%) and 200-500 m (10.35%) and the biomass obtained were 869t, 853 t, and 661 t respectively. Poor catches of 558 t (8.73%) and 349 t (5.46%) were recorded from the waters with depths of above 3000 m and 500-1000 m respectively (Figure 57).

About 1833 t (39.95%) of the pelagic shrimps were caught from deeper waters with depth range of 2500-3000 m during night. 736 t (16.05%) and 667 t (14%) of the catches were from waters with depth range 2000-2500 m and 500-1000 m respectively. Low catches of 568 t (12.38%) and 363 t (7%) were recorded from stations with depth range of 1000-1500 m and 200-500 m respectively (Figure 57).

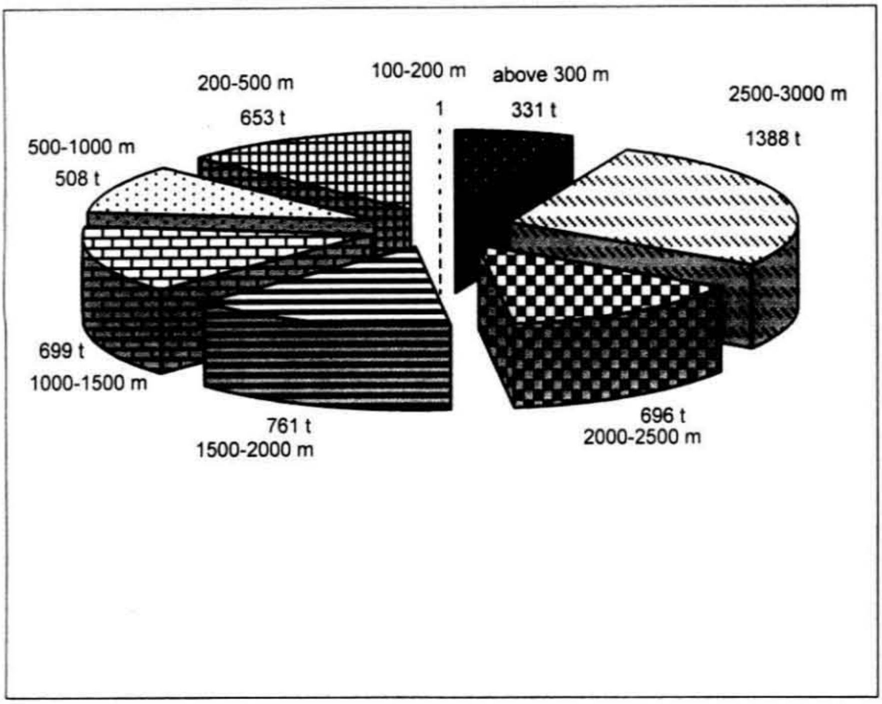

Figure 56. Depthwise biomass (t) estimation

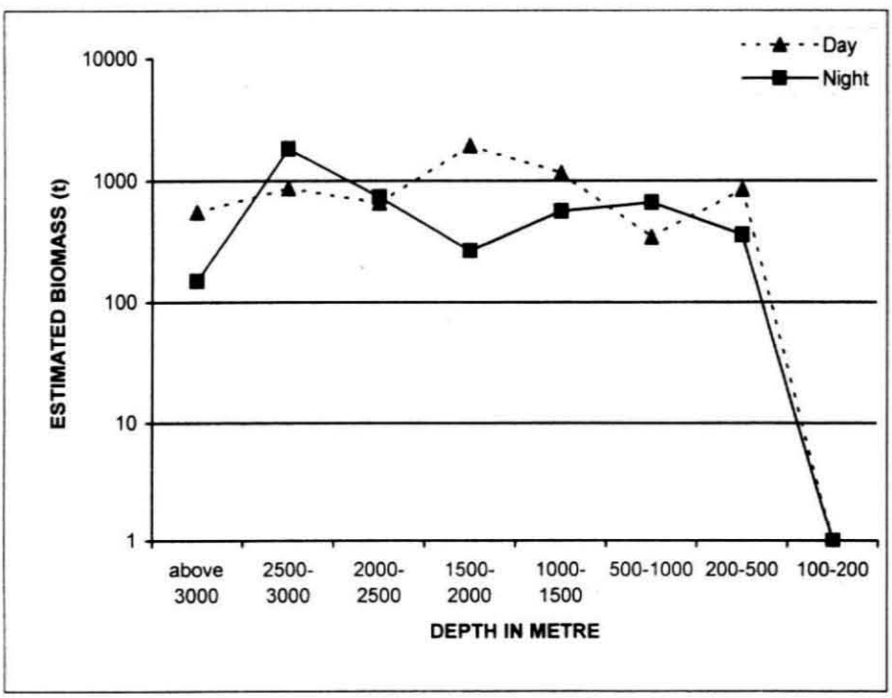

Figure 57. Biomass(t) estimation in relation to day and night hauls

3. 4 .3 SEASONWISE ESTIMATED BIOMASS

An attempt was made to study the seasonal pattern in the occurrence and distribution of pelagic shrimps. Due to the profound influence of southwest monsoon on the distribution and abundance of most of the major fishery resources in Indian waters, the calender year has been classified into Pre – Monsoon (February– March), Monsoon (June- September) and Post- Monsoon (October- January), in order to understand the seasonal abundance of the resources.

Biomass estimation

The seasonal distributional studies of pelagic shrimps in the DSL showed that an average biomass of 545 t (48.53%) was recorded during pre-monsoon season followed by monsoon season with an average value of 298 t (26.54%) and lowest catch of 280 t (24.93%) was recorded during the post-monsoon season (Table 3).

Diurnal variations

The most productive season for pelagic shrimps was found to be monsoon season, which yielded about 183 t (75.93%) during day. Pre-monsoon recorded a biomass of 40 t (16.6%). The low catches of 18 t (7.47%) were obtained during the post-monsoon season (Table 4).

The seasonwise distribution of pelagic shrimp showed that the rich concentration of 505 t (57.26%) were recorded during pre-monsoon season and followed by 262 t (29.71%) during post-monsoon at night. Very low catch of 115 t (13.03%) were recorded during the monsoon season at night. (Table 5)

Table 3. Seasonwise estimated biomass of pelagic shrimps (Day and Night)

Seasons	Biomass (t)	% Of Biomass
Pre-Monsoon	545	48.53
Monsoon	298	26.54
Post-Monsoon	280	24.93

Table 4. Seasonwise estimated biomass and their percentage of pelagic shrimps (Day)

Seasons	Biomass (t)	% Of biomass
Pre-Monsoon	40	16.6
Monsoon	183	75.93
Post-Monsoon	18	7.47

Table 5. Seasonwise estimated biomass and their percentage of pelagic shrimps (Night).

Seasons	Biomass (t)	% Of biomass
Pre-Monsoon	505	57.26
Monsoon	115	13.03
Post-Monsoon	262	29.71

3. 4. 4 LATITUDEWISE ESTIMATED BIOMASS

Biomass estimation

High biomass values were found at 6° latitude (5,057 t; 30.75%) followed by 14° latitude (2,049 t; 12.46%), 08° latitude (1,813 t;11.02%), 10° latitude (1,616 t; 9.83 %), 13° latitude (1,279 t; 7.78%), 9° latitude (1,194 t; 7.26%), 11° latitude (1,168 t; 7.1 %) and 07° latitude (9,22 t; 5.6 %). Lowest values were recorded in 15° - 21° latitude (Table 6).

Diurnal variations

During day, 26.94 % (2,450 t) of the catch was found at 6° latitude followed by 14° latitude. (22.53%; 2,049 t), 10° latitude (13.22%; 1,207 t), 11° latitude (12.85%; 1,168 t) and 7° latitude (9.16%; 8,33 t). The very low catches were recorded from other latitudes (Table 7).

During night, a maximum of 35.45 % of the catch (2,607 t) was recorded at 06° latitude followed by 08° latitude(22.09%;1,625 t), 13° latitude (13.96%; 1,027 t) and 9° latitude (11.06%;813 t) (Table 7).

Table 6. Estimated latitudewise biomass of pelagic shrimps in the west coast of India.

LATITUDE	BIOMASS (t)	% OF BIOMASS
6°	5,057	30.75
7°	922	5.61
8°	1,813	11.02
9°	1,194	7.26
10°	1,616	9.83
11°	1,168	7.10
12°	700	4.26
13°	1,279	7.78
14°	2,049	12.46
15°	191	1.16
16°	205	1.25
17°	129	0.78
18°	2	0.01
19°	7	0.04
20°	63	0.38
21°	50	0.30

Table 7. Latitudewise day and night variations in abundance of pelagic shrimps in the west coast of India

LATITUDE	DAY		NIGHT	
	BIOMASS (t)	% OF BIOMASS	BIOMASS (t)	% OF BIOMASS
6°	2,450	26.94	2,607	35.45
7°	833	9.16	89	1.21
8°	188	2.07	1,625	22.09
9°	381	4.19	813	11.06
10°	1,207	13.22	409	5.56
11°	1,168	12.85	0	0
12°	362	3.98	338	4.6
13°	252	2.77	1,027	13.96
14°	2,049	22.53	0	0
15°	13	0.14	178	2.42
16°	23	0.25	182	2.47
17°	115	1.26	14	0.19
18°	1	0.01	2	0.03
19°	0	0	7	0.1
20°	2	0.02	63	0.86
21°	50	0.55	0	0

3. 5 DISCUSSION

The quantitative richness of the DSL is mainly due to the presence of micro nektonic organisms like pelagic shrimps, swarming crabs, cephalopods and mesopelagic fishes. The deep scattering layers harbour rich and varied population of pelagic shrimps throughout the Indian EEZ. Among the scattering layer pelagic crustaceans occurring in the sea, shrimps appear to occupy prime position in numerical abundance (Suseelan and Manmadan Nair, 1990).

Pelagic shrimps belonging to several families formed the major component (numerical) among the nektonic groups. The pelagic shrimps population was predominantly constituted by 11 families namely, Penaeidae, Benthsicymididae, Solenoceridae, Sergestidae, Luciferidae, Oplophoridae, Nematocarcinididae, Pasiphaeidae, Pandalidae, Thalassocaridae, and Stenopodidae and 19 genera, *Pelagopenaeus, Funchalia, Gennadas, Solenocera, Hymenopenaeus, Sergestes, Sergia, Acetes, Lucifer, Oplophorus, Acanthephyra, Meningodra, Notostomus, Nematocarcinus, Leptochela, Psathyrocaris, Plesionika, Thalassocaris and Stenopus* with many number of species. There are about 2,000 species of shrimps (Macurua, Natantia) in the world. At least 200 of these species pass their entire life in the pelagic phase (Omori, 1974). Menon and Prabadevi (1990) observed 17 groups of planktonic organisms in the DSL and the macronektons of the DSL were composed of crabs, cephalopods and fishes. The distribution of pelagic shrimps shows a clear north-south variation with regard to abundance, increasing from north to south. The pelagic shrimps catches accounted off the south west coast (6^{o}-15^{0} N) for about 64.75%, of the total catch hauled. The south west coast is found to be more productive for pelagic shrimps when compared to the north west coast of India where, their abundance is rather patchy and productive areas are less extensive. Suseelan and Manmadan Nair, (1990) also made similar observation. Omori (1974) stated that the distributions of many shrimps are uneven and patchy, probably shoaling might occur as a result primarily of intraspecific interaction of the shrimps, although its mechanisms and functions are not well known.

The maximum population densities were recorded off Vizhinjam (106.4 nos./1000 m^3), and off Cochin (100.8 nos./1000 m^3). The catches of the northwest coast (15^0 - 22^0 N) formed about 35.26% and good catches were recorded off Ratnagiri region (51.1 nos./1000 m^3). The present observations on abundance are more or less similar to that of the findings of Suseelan and Manmadan Nair (1990).

High concentration of pelagic shrimps at 06° to 10° N and 16° to 17° N latitude shows that it may be due to the presence of very high density pockets of zooplanktons off Cochin (1,228.32 cc/1000 m^3 at 09° 00'N 76 ° 19'E) and off Mangalore (1,968.25 and 1,527.51 cc/1000m^3at 10° 30'N 75° 40'E and 11°30'N 75° 30'E respectively (Mathew ans Natarajan, 1990). According to Suseelan and Manmadamadan (1990) the maximum abundance of shrimps was recorded in 09-75, 11-75 and 18-72 degree squaress where the catch rates exceeded 2,000 nos./haul. The greatest density of over 10,000 -nos/haul was observed in the 18-75 degree squares off Bombay-Ratnagiri coast in Maharastra during December.

Distinct diurnal migrational pattern of pelagic shrimps in Indian seas is evident from the day and night variations observed in the IKMT catch (Suseelan and Manmadan Nair, 1990). Changes in the abundance of pelagic shrimps during day and night could throw light on the nature of vertical migration of these crustaceans of the DSL, which is characterized by cyclic changes in position in the upper columnar region of the sea with the changes in day and night (Menon and Prabadevi, 1990). Accordingly they ascend to epipelagic realm during night and descend to deeper waters during day.

The average density of shrimps at night was higher than during day was also confirmed by Suseelan and Manmadan Nair, (1990). Pearcy and Laurs (1966) reported day and night differences in the number of certain species and groups of organisms, at depths of 400 m and 800 m, indicate not only that the animals of the deeper waters but also for certain species of the midwater undergo daily migrations over considerable distances. Light is probably the only day to night variable at a depth of 800 m, or approximately one half mile, hence differences in light intensity must be largely responsible for these movements. There are suggestions that a physiological rhythm may in part, be responsible for their behaviour.

Shrimps feed actively at night, however physiological evidence suggests that the lower meso-and bathypelagic species are able to maintain their predatory activities throughout their range of migration, by day as well as by night (Pearcy and Laurs, 1966). Waterman *et al.* (1939) stated that diurnal vertical migrations have long been known to play an important part in the lives of pelagic organisms.

Foxton (1970b) showed a similar phenomenon in the vertical distribution of the species in the genera *Gennadas, Sergestes, Sergia* and *Systallaspis*. He suggested that solar radiation and its penetration into the sea must be of prime importance in relation to such patterns of vertical distribution. There is now a considerable amount of evidence to show that mesopelagic organisms having restricted vertical ranges and particularly for those associated with sonic scattering layers that correlate strongly with the light intensity at their depth of maximum abundance (Clarke, 1966; Boden and Kampa, 1967). Such organisms apparently adjust their depth distribution to some optimum submarine light regime and migrate in response to variations, diurnal or short term in light intensity (Clarke and Backus, 1956; Blaxter and Currie, 1967). Such correlations have not so far been established for any of the decapod species considered here but the nature of their daytime distributions, which consist of a series of overlapping layers and the fact that most undergo a night migration suggests that the penetration of solar light in to the sea may be an important factor underlying their behaviour. The observed variations in pigmentation and photophores could thus represent adaptations to the particular light regimes of the shallow and deep mesopelagic habitats. The average density of shrimps during night was higher than during day was also confirmed by Suseelan and Manmadan Nair, (1990). There is, however, some indication that deep – water animals anticipate sunrise as Clarke (1934) found certain shallow water forms such as *Metridia* sp do. Diurnal rhythms are known to persist for considerable lengths of time in the absence of regularly recurring changes in light intensity (Welsh, 1936).

In the present observations based on the numerical biomass of pelagic shrimps of the west coast of India shows that the concentration was mainly in the waters > 1000-3000 m particularly in the night, which clearly shows that there are chances of horizontal migrations as well during their movement up and down the water column. At night the animals were more densely packed in the depth range of 0-200 m operational range. Whereas, during day these animals usually appeared at depth of 200 m and deeper. Omori (1974) stated that usually the shrimps living above 500 –700 m depth by day are transparent or semitransparent with scattered red chromatophores. At about 500-700 m a sudden faunal change occurs and the upper mesopelagic species are being replaced by those having a typically uniform scarlet-red pigmentation. The pigmentation is not distinct in younger stages, but the body gradually turns red in adults with increasing depth of occurrence, as observed in *Systellaspis debilis*.

Omori (1974) stated that generally, the shrimps occur at depths where the food supply is greatest. Their distribution is concentrated in depths where more food (copepods and other mesoplankton) descending from upper layers are available. Therefore, they form comparatively thin layers in shallower depths and in poorly productive areas, whereas they are denser in the productive areas. According to Vinogradov (1968), in the subarctic region of the north Western Pacific where it is highly productive, the shrimp biomass gradually increased below 500 m, reaching the maximum in 1000-3000 m depths. Vinogradov (1961) considered the possible pathways by which organic matter could be transferred from the surface to abyssal depths of 8,000 m using migratory routes. The tentative scheme presented above shows that pelagic shrimps to some extent produce spatially such a " ladder of migrations" at least in the upper 1,000 m stratum.

The family Pasiphaeidae was the most abundant and frequently occurring family with an average catch of 11 nos./1000m^3 in areas between 07°- 21° N and 77-76° E. The maximum densities of 178 nos./1000 m^3 were recorded off Cochin in the night collections and the depth of operation was 50 m. Night catches was more when compared to the day catches. The family Pasiphaeidae was fished out more in the depth range of 0-50 m and 50-200 m.

The family Thalassocarididae formed the numerically dominant group and it was obtained only from the southwest coast (07°–14'N and 67°–77'E) and the more productive areas identified were off Vizhinjam, and off Cochin. It yielded maximum catch in the operational depth of 50-200 m, mostly during nighttime. It was available only up to 400 m depth during daytime. Horizontal distributional studies suggest that these shrimp families were more in the deeper parts of the ocean.

The family Sergestidae recorded both during day and night from the areas between 06°–21'N and 66°-77'E. It is distributed along the near shore, off shore and oceanic region. The maximum abundance was recorded off Cape Comorin. Night catches were more abundant than during day. In the operational depth up to 200 m fairly good catches were obtained during night. Day catches were poor. Dense concentrations were recorded in the (station) depth of 2500-3000 m and 1500-2000 m.

Another important family Oplophoridae, was recorded from the area of 08 ° –18' N and 67 °-76' E. It was abundant more in the southwest coast from off Cape Comorin to off Mangalore. The maximum catch was recorded off Vizhinjam. The catch was fairly good at night and the day catch was poorly represented. Good catches were recorded from waters with depth of 1500-2000 m. It was interesting to note that the catch was available in all the depth ranges except shelf areas (100-200 m).

The (quantitative) biomass (tonnes in 1° squares) of the pelagic shrimp was found to be increasing with increasing depth of operation. The catch was maximum in the (operational) depth above 300 m. The shrimps were more abundant in depths above 300 m during day. At night, almost equal quantities of pelagic shrimps were present at surface down to 200 m (43.63%) and above 300 m. These findings, show that not all pelagic shrimps undergo vertical migrations during every diel period and some tend to remain in deeper waters even at night. This can be cited as an example for resource partitioning within the specific groups and there shrimps that remains in the deep do contribute sizable to the non-migrating DSL.

The highest catch recorded was 1,388 t from the deeper water stations with depth of 2500-3000 m. Next higher values were observed in the shelf breakwater region (2000-2500 m) with a catch of 696 t and during night, high values were recorded from waters above 2500-3000 m (1,837 t) while during day pelagic shrimps were found to concentrate in the waters above 1500-2000 m (1,939 t). Generally, the pelagic shrimps were available in plenty during pre-monsoon season with a catch of 48.53% (545 t) and next peak abundance was observed during the monsoon season (298 t).

From the estimated biomass of pelagic shrimps it was found that 30.75% of the catch was recorded from 6° N with a catch of 5,057 t followed by relatively good catche of 12.46% (2,049 t) from 14° N. The area 08° N latitude was the next productive with a catch of 1,813 t. It shows that higher latitude particularly above 15° N recorded low catches whereas catches from 06-11° N were good.

CHAPTER 4

FOOD AND FEEDING HABITS OF *Oplophorus typus*

CHAPTER 4

FOOD AND FEEDING HABITS OF *OPLOPHORUS TYPUS*

Systematic position of *O.typus*

Class	: Crustacea
Order	: Decapoda
Infra-order	: Caridea
Super Family	: Oplophoroidea
Family	: Oplophoridae Dana, 1852
Genus	: Oplophorus H. Milne-Edwards, 1837
Species	: *Oplophorus typus* H. Milne-Edwards, 1837

Fig. 58

4. 1 INTRODUCTION

The study of food and feeding habits of commercially important shrimps is essential for understanding the various aspects of biology such as growth, development, reproduction and migration. Knowledge on the diet of shrimps is important in fundamental community analysis for studies of food webs, trophodynamics, and resource partitioning and ecological energetics (Ivlev, 1961 and Landenberger, 1968). An understanding of the relationship between shrimps and food organisms especially the favorite food items and their seasonal distribution may help to locate the potential feeding grounds and as clue for the prediction and exploitation of fish stocks.

Food is an important factor in the biology of fishes and shellfishes to the extent of governing their growth, fecundity and migratory movements. Variations in the seasonal and diurnal abundance of the favorite food organisms of different species of fish and shellfish, in any region, may influence respectively the horizontal and vertical movements of the fish stocks. Hence, a correct knowledge of the relationship between the fishes and food organisms is essential for the prediction and exploitation of the fish stocks. An objective study of this relationship should be properly integrated in the orientation of a commercially exploited fishery, taking into account, the diversity of the component species constituting the total fishery of the region. The distribution, occurrence and abundance of finfish and shellfish mainly depend on the availability of food. Gut content analysis and features of the alimentary system provide information on food, feeding habits and selective feeding if any in fish and shellfish. Studies on the food and feeding habits of fishes and shell fishes envisage knowledge on the food preference and influence of age, time season and stages of mortality, which are of atmost importance in both the capture and culture fisheries.

Generally, decapod crustaceans are predators or omnivores and can utilize various kinds of food. They may scavenge decomposing dead material in addition to taking living pray. Gut contents of pelagic shrimps are usually well macerated and mostly unidentifiable. This amorphous material appears to consist primarily of crustacean fragments and mattered aggregations of fibrous and granular debiris. Some may have originated from digested phytoplankton. At any rate, this is not entirely the result of digestive processes, but also arises from the decapods nature of the material at the time of its ingestion. The recognizable remains include small crustaceans, calanoid copepods, chaetognaths, and diatoms, foraminifers, hooks of chaetognaths and fish scales that are frequently present. There is also some indications of cannibalism.

Decapods were assigned to five different trophic groups according to the food resources exploited and feeding strategy employed (macroplankton feeders, macroplankton-epipelagic feeders, epibenthic feeder, epibenthic-endobenthic feeders, and deposit feeders). There was little dietary overlap, indicating that species did partition the available resources, overall, dietary overlap values among species increased with depth (Cartes, 1998). Flock and Hopkins (1992) examined the food of 11 sergestid species and found that they are predators on other crustaceans. They analyzed the food content of *Sergestes henseni, S. paraseminudus, S. atlanticus, S. sargassi, S. pectinatus, S. curvatus, S.vigilax, S. edwardsii, S. armatus, Sergia robustus, and S. splendens.* Genthe (1969) reported the food of *Sergestes similies* of the Santa Barbara Basin. Cartes (1993) studied the food and feeding of 6 species of pelagic shrimps such as *Pasiphaeia multidentata, Aristeus antennatus, Acanthephyra eximia, Plesionika martia, P. edwardsii and P. acanthonotus*, of Catalan sea (Western Mediteranean). The same author also studied the food analysis of *Acanthephyra eximia* and *A. pelagica* of the Oplophoridae in the same area. The feeding of shrimps, links zooplankton and large animals of higher trophic level in the food chains and transports organic matter produced in the upper layers to the lower layers. Omori (1974) stated that the most of the pelagic shrimps such as *Aectes chinensis, A. erythraeus, Peisos petrunkevitchi, Sergia lucens, S. prehensilis, S. joponicus, Sergestes similes, S. arcticu, S. seminudus, Pasiphae pacifica, P. multidentata, Oplophorus gracilirostris, O. spinosus, Systellaspis debilis, Acanthephyra quadrispinosa, Acanthephyra purpurea, Bentheogennema boreali, Hymenodira glacilis* and *Physetocaris micropthalma* feed mainly on detritus or debris, crustacean parts, copepods, fish remains, ampipods, euphausiids, ostracods, chaetognaths, etc. The young ones of *Oplophorus* *noraealandiea* feed mainly on copepods and chaetognaths and with age shrimps feed mainly on macroplankton, fish and euphausiids (Burukovskij, 1994)

However, no information is available on food and feeding habits of *O. typus* from the Indian waters at present. The present work gives a detailed account on the food and feeding habits of *O. typus*.

4. 2 MATERIALS AND METHODS

Samples of *O. typus*, collected by the Isaac Kidd- Mid water Trawl (IKMT) net on board FORV *Sagar Sampada* during October 1998 – May 2000 in the west coast of India were analyzed to study the food and feeding habits of this species. A total of 412 species was used for the study. Figure 59 shows the area of occurrence of *O. typus* in the west coast of India.

It is very difficult to identify the food items, species wise due to the nibbling action of mandibles on the food and mastication of food inside the stomach by the action of gastric mill. The identification of food organisms was based mainly on broken shell remains, spines, setae etc. The gut contents were grouped as detritus, chaetognaths, crustacean remains (other than shrimps i.e, crab parts, decapods and other crustaceans) fish remains, shrimp remains (exclusively of shrimps and shrimps parts), euphausiids, diatoms copepods and foraminifera. Various methods are in prevalence in the studies of stomach analysis of fishes and these were critically discussed by Hynes (1950) and Pillay (1952). Since the quantity of food in the stomach of prawns is very little, instead of volumetric methods, the points (volumetric) method (Pillay, 1952) was utilized for studies on the food and feeding habits of *O.typus*. In order to get a summary picture of frequency of occurrence as well as volume of various items Natarajan and Jhingaran (1961) devised a method called 'Index of Preponderance' for studying the food and feeding habits of fishes. This method was adopted here for studying the food and feeding habits of *O. typus*. This method is explained here briefly. If V_i and O_i are the Volume and Occurrence index of food item i, the combined Index (I) for food i may be presented as,

$$I_i = \frac{Vi\ Oi}{\sum Vi\ Oi} \times 100$$

The sum of all items leads to 100. The Index designated as the Index of preponderance is in actuality, is a composite one based on Volume and Occurrence index.

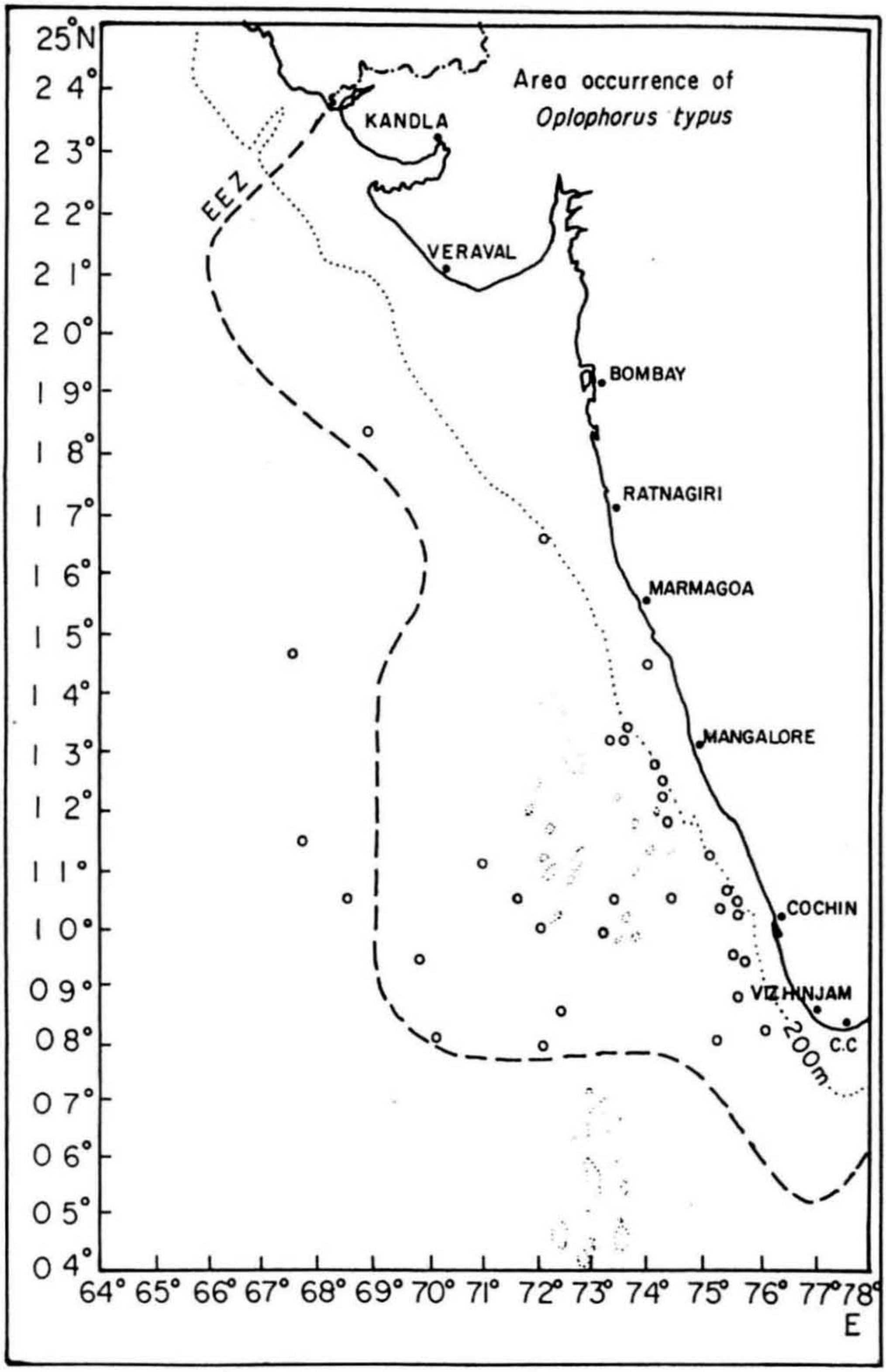

Figure 59. Distribution of *O.typus* in the west coast of India.

The Index of Preponderance provides a definite and measurable basis for grading the various food elements as it gives a combined picture of frequency of occurrence as well as bulk. The degree of fullness of stomach in relation to size of shrimps was noted to study the intensity of feeding in different months. From the total number of shrimps examined in a month, the percentage occurrence of stomachs with different intensities of feeding was computed. The intensity of feeding was determined by the degree of distension of the stomach due to the quantity of food inside the proventriculus. The condition of feed was expressed as full, ¾ full, ½ full, ¼ full, trace and empty and each one was assigned 100, 75, 50, 25, 10 and 0 points respectively. The stomach was cut open and the contents examined under a microscope. Percentages of occurrence of the various food items were calculated for individual shrimp. Depending on the relative volume of each food item, points were given and a volume of each food item was calculated. The percentages occurrence of individual food items in the stomach contents in different months, depths, time, and day and night hauls were determined by assuming the total number of occurrence of all the food items from which the percentage occurrence of each item was calculated. The indices of preponderance were then computed to indicate the food preference of *O. typus*

4. 3 RESULTS

A study on the stomach contents and feeding habits of the deep sea pelagic shrimps *Oplophorus typus* collected by the IKMT net from the West coast of India, during October 1998-May 2000 was carried out in detail. The details of the composition of food during different months, at different depths, during different time, and intensity of feeding were studied. Change in feeding habits between day and night was also observed. The result revealed that the pelagic deep-sea shrimp, *O. typus* is an omnivore, feeding on 1. detritus 2. chaetognaths 3. crustacean remains 4. fish remains 5. shrimp remains 6. euphausiids 7. diatoms 8. copepods and 9. foraminifera in the order of abundance

4. 3. 1 COMPOSITION OF FOOD

The pelagic shrimp, *O. typus* feeds mainly on detritus followed by crustacean remains, chaetognaths, etc. The food abundance as per the Index of Preponderance was 1. detritus 2. chaetognaths 3. crustacean remains 4. fish remains 5. shrimp remains 6. euphausiids 7. diatoms 8. copepods and 9. foraminifera (Figure 60).

Detritus, crustacean remains, euphausiids, and diatoms were observed in their guts during the entire period of investigations. The other food items, which appeared during certain months, were chaetognaths, fish remains, shrimps remains, copepods, and foraminifera. The monthwise details of Index of preponderance (here after referred as Index) for each food item as well as the annual Index are given in Table 8.

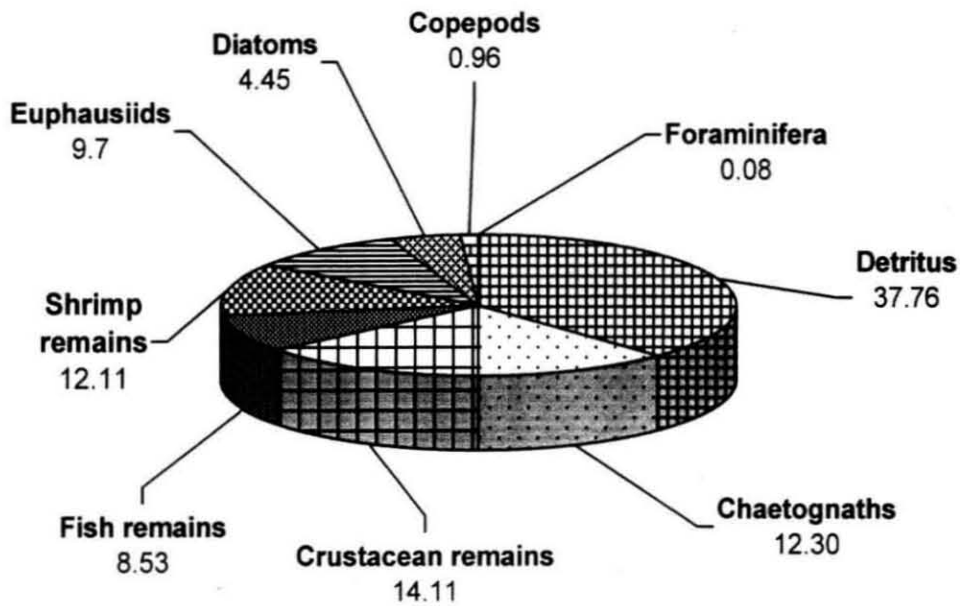

Figure 60. Food composition of *O. typus*

The details of food components

Detritus : The most predominant food item of *O. typus* was detritus (Index of Preponderance 37.76) and it was observed in all months. It ranked first among the food items in April, October and December.

Crustacean remains : Crustacean remains consisted mostly small crab bits, mysid bits and other unidentifiable crustacean bits, which formed second among the food item with an Index of 14.11 during 1998-2000. It ranked second among the food items in June with an Index of 20.95 and ranked third in October with an index of 24.71.

Chaetognaths : Chaetognaths were found as important food item of this species with an Index of 12.30. The maximum Index of 19.57 was noticed in June and occupied third position among food items. Chaetognaths were the second important food item in December with an index of 17.5.

Shrimps remains : Shrimp remains (fragments of pereopod, antennae, mandibles, telsons jointed with uropods) and ranked fourth in the order of abundance with an Index of 12.11. It formed second important food item during October with an Index of 26.34.

Euphausiids : Euphausiids ranked fifth in the order of abundance with an Index of Index of 9.7. It ranked first among the food items in May with an Index of 23.86.

Fish remains : Fish remains consisted of scales, bones, spines, otoliths and eye lenses of fishes. They constituted sixth important food item with an Index of 8.53. Mostly parts of small fish were found in the stomach. They formed one of the most important food items during May and April with on Index of 19.2 in each month.

Table 8. Index of preponderance of food item in the stomach contents of *O.typus* in the IKMT catch

MONTH	APRIL	MAY	JUNE	OCTOBER	DECEMBER	TOTAL
Detritus	50.07	18.94	18.21	27.42	74.16	37.76
Chaetognaths	12.02	12.43	19.57	-	17.5	12.30
Crustacean remains	11.39	10.55	20.95	24.71	2.97	14.11
Fish remains	19.2	16.4	5.6	1.43	-	8.53
Shrimp remains	2.93	5.34	25.92	26.34	-	12.11
Euphausiids	1.15	23.86	3.71	19.51	0.26	9.7
Diatoms	2.64	8.85	5.06	0.59	5.11	4.45
Copepods	0.6	3.21	0.98	-	-	0.96
Foraminifera	-	0.42	-	-	-	0.08
Sample size	211	94	43	33	31	421

Diatoms : Diatoms were present throughout the period of observation and occupied seventh place with an Index of 4.45.

Copepods : Copepods ranked eighth among the food item with an index 0.96. They were present as a food item during April (0.6), May (3.21), and June (0.98) only.

Foraminifera : Foraminifera were found in very small quantities during May with an Index of 0.08. They ranked last among the food items.

Males :

Detritus formed (Index of 43.53) the major food item of male *O. typus*. They fed mainly on detritus in April (34.94) followed by chaetognaths (22.72) and fish remains (17.72). This trend continued in May also, with detritus (28.59) forming first preferable item followed by euphausiids (22.07) and chaetognaths (15.65). In October detritus (39.06) and euphausiids (30.90) contributed the major feed. In December their most preferred food item was detritus (71.53) followed by chaetognaths (13.62) and diatoms (10.22) (Table 9).

Females :

Like males, the main food for females was also detritus (37.05). In April, it prefered mainly detritus (65.2) and fish remains (20.68). During May it fed mainly on euphausiids (25.65) and fish remains (25.27). During June they fed on shrimps remains (25.92), crustacean remains (20.95), chaetognaths (19.57) and detritus (18.21). Shrimps remains (52.68) and crustacean remains (22.24) were the major food items during October. In December it mainly consumed detritus (76.78) followed by chaetognaths (21.37) (Table 9).

Table 9. Index of preponderance of food items of males and females of *O. typus*

MONTH	APRIL		MAY		JUNE		OCTOBER		DECEMBER		TOTAL (AVG)	
SEX	M	F	M	F	M	F	M	F	M	F	M	F
Detritus	34.94	65.2	28.59	9.28	-	18. 21	39.06	15.77	71.53	76.78	43.53	37.05
Chaetognaths	22.72	1.32	15.65	9.21	-	19.57	-	-	13.62	21.37	13	10.29
Crustacean remains	17.70	5.08	3.74	17.36	-	20.95	27.17	22.24	4.63	1.32	13.31	13.39
Fish remains	17.72	20.68	7.52	25.27	-	5.6	2.87	-	-	-	7.03	10.31
Shrimp remains	1.31	4.55	10	0.69	-	25.92	-	52.68	-	-	2.83	16.77
Euphausiids	0.06	2.25	22.07	25.65	-	3.71	30.90	8.12	-	0.53	13.25	8.05
Diatoms	4.43	0.85	12.11	5.59	-	5.06	-	1.19	10.22	-	6.69	2.54
Copepods	1.12	0.07	0.32	6.10	-	0.98	-	-	-	-	0.36	1.43
Foraminifera	0	0	0	0.85	-	-	-	-	-	-	-	0.17
Nos. shrimp observed	118	93	39	53	-	43	25	8	15	16	198	214

M = Males   F = Females

4. 3. 2 VARIATION OF FOOD IN RELATION TO DAY AND NIGHT

The food and feeding habits of pelagic deep-sea shrimp, *O.typus* hauled by IKMT during day and night were compared for studying the diurnal variations. Though there was noticeable difference in selectivity of food items during day and night, detritus formed as the major component of the food irrespective of the time factor.

In day hauls (06-18 hrs), the dominant food items were detritus (Index, 30.32) and chaetognaths (Index 18.98), which together contributed to half of its food requirments. The other prey items present in the order of abundance were crustacean remains (15.9), fish remains (14.78), shrimp remains (13.92) and other components. Detritus (34.77) and euphausiids (15.51) formed about half of the food requirements of *O. typus* in the night hauls (18-06 hrs). The other major components in the gut contents were crustacean remains (11.75), chaetognaths (10.78) and, fish remains (10.13) and others. Foraminifera ingested in less quantity during day hauls. It is observed that chaetognaths, crustacean remains, fish remains and shrimp remains were consumed more in the day time and less in night time. The euphausiids, diatoms and copepods had higher index during night hauls than the day hauls (Figure 61).

Males :

During day males prefer mainly detritus (34.34) followed by chaetognaths (29.71) and fish remains (15.12). It is very interesting to note that the male *O.typus* did not feed on shrimp remains during nighttime. Detritus formed almost one-third during night. Night samples of male showed that they prefer detritus (37.64) followed by crustacean remains (18.84),euphausiids (12.61),diatom (12) and fish remains (9.47) (Figure 62).

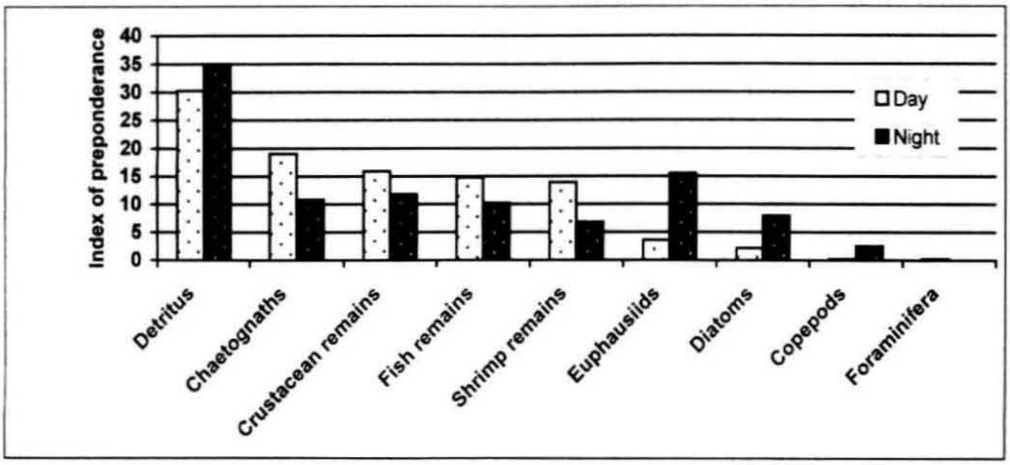

Figure 61. Relative importance of food item in *O.typus* during day and night hauls.

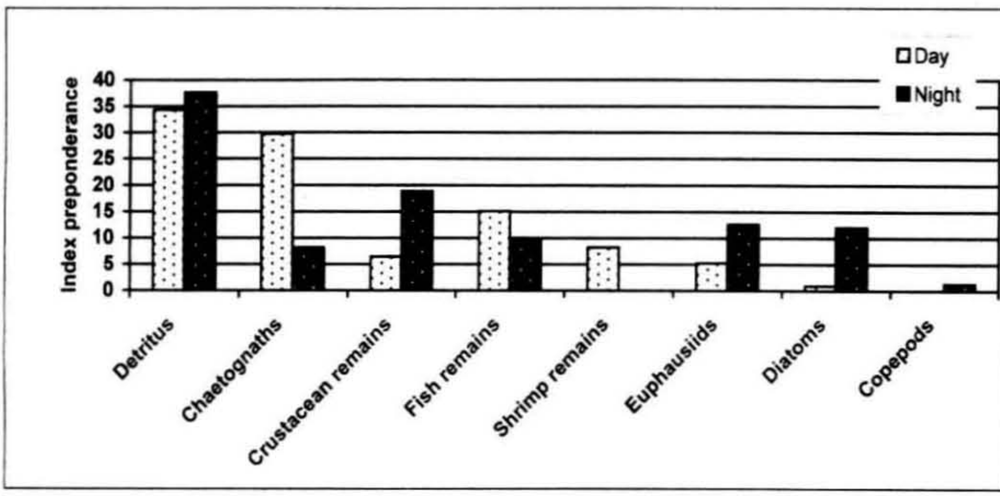

Figure 62. Relative importance of food item in male of *O.tupus* during day and night hauls

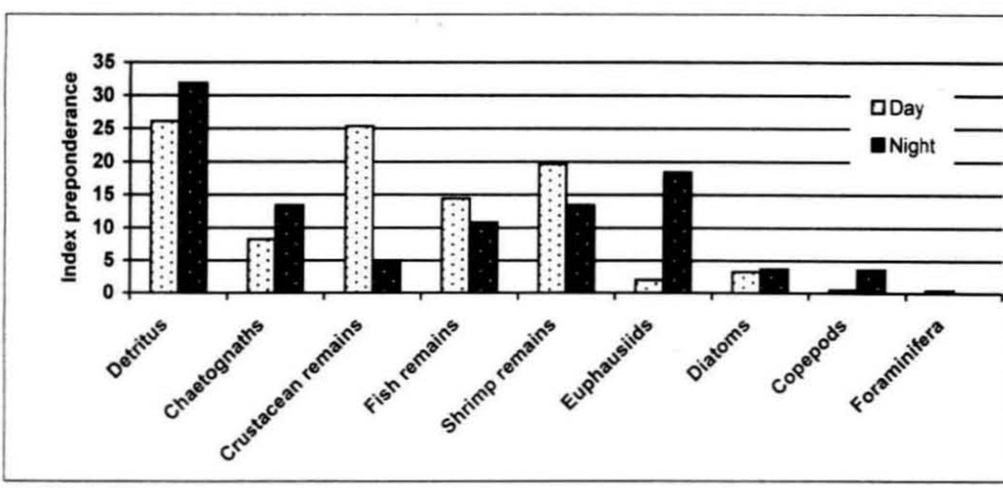

Figure 63. Relative importance of food item in females of *O.tupus* during day and night hauls

Females :

Analysis of the day samples showed that female *O. typus* prefered detritus, which, contributed to one-fourth of their food requirements. Both detritus and crustacean remains put together contributed to 50% of the food requirements. Detritus formed one of the most important food items during night. Detritus (31.89) and euphausiids (18.42) together formed about 50% of the food. The other items preferred by *O. typus* during night was shrimp remains (13.46), chaetognaths (13.41) and fish remains (10.29) (Figure 63).

4.3 .3 VARIATION OF FOOD IN RELATION TO TIME

For the purpose of study on the variations in food of *Oplophorus typus,* the food analysis was carried out at four hourly intervals of 00-04, 04-08, 08-12, 12-16, 16-20, 20-24 hrs. The percentage of occurrence of each food item during these time intervals is presented in Figure 64.

There was no collection during 00-04 hrs. During the sunrise period (04-08 hrs), *O. typus* mainly fed on shrimp remains (Index, 40.14), chaetognaths (24.62) and detritus (22.36). During 08-12 hrs, the main food was detritus (31.69), and crustacean remains (31.26). Small quantities of chaetognaths, shrimp remains, and diatoms were also found in the stomach. Crustacean remains (24.31), fish remains (17.56), shrimp remains (17.61) constituted the main food of during 12-16hrs. Other food items were present in negligible quantities. At night (20-24 hrs), it fed mainly on detritus (28.32) and euphausiids (28.13). The next important items were chaetognaths (14.01) and diatoms (12.91). Other items were found in insignificant quantities.

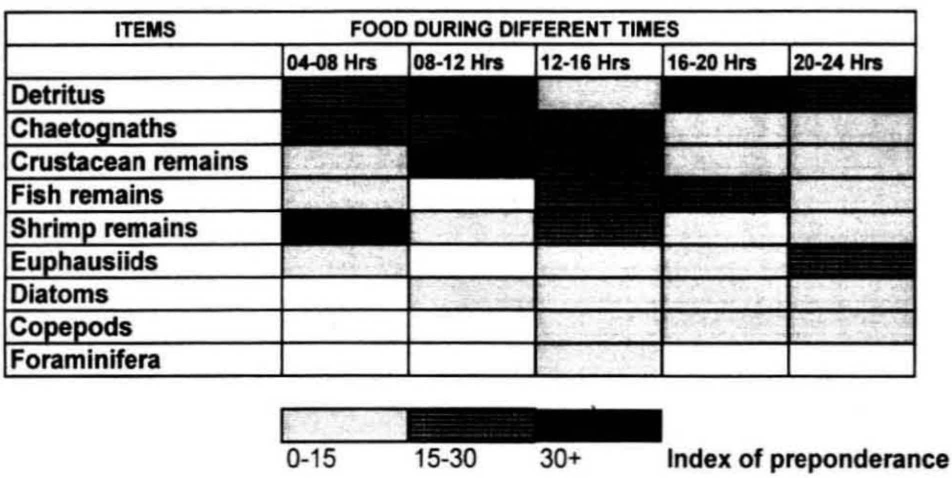

Figure 64.Index preponderance of food item of *O. typus* in different hours

4.3.4 FOOD IN RELATION TO DEPTH

Variations in food preferences of *O. typus* in different depth zones were studied. The samples were analyzed for 8 depth zones namely, 0-100 m, 100-200 m, 200-300 m, 300-400 m, 400-500 m, 500-600 m, 600-700 m and 700-800 m.

In general, the deep-sea pelagic shrimp *O. typus* feed on various organisms in different depths. In lower depth of 0-100 m, they mainly fed on detritus (Index of 59.19) and chaetognaths (18.48). At the depth range of 100-200 m, they fed on detritus (21.4), shrimps remains (19.04), fish remains (18.96), crustacean remains (12.08), diatoms (12.07) and others. They fed groups mainly on euphausiids (33.35), detritus (18.91), shrimps remains (15.02), crustacean remains (14.61) and others in the depth range of 200-300 m. In the 300-400 m depth range, detritus (37.12) and fish remains (20. 73) followed by almost equal representation of chaetognatha and crustacean remains (17.68) formed the main food items. Chaetognaths (60) and fish remains (40) were the two food items present in the samples collected from the depth of 400-500 m. In the deeper waters of 700-800 m depth range, *O.typus* ingested mainly crustacean remains (31.44), detritus (29.05), shrimp remains (21.43) and euphausiids (15.45) and others, in the order of abundance (Table 10).

In the depth of 0-100 m detritus (35.12) and Chaetognaths (30.15) were the main food for females on *O. typus* and for males the feed was mainly detritus (83.25). At 100-200 m, the females fed mainly on shrimps (38.08) and detritus (26.52) and the males consumed mainly diatoms (24.14) and fish remains (23.98). The females and males of *O. typus* in the depth range 200-300 m consumed mainly euphausiids and detritus. At the depth of 300-400 m, detritus (37.85), fish remains (22.54) and crustacean remains (23.03) were formed the major food of female *O.typus,* and males fed on detritus (36.40) and chaetognaths (27.9). At 400-500 m depth, males preferred only chaetognaths (60) and shrimps (40) and females were not collected from this depth. In the depth range 700-800 m, females consumed mainly shrimp remains (42.86) and crustacean remains (35.72) whereas males ingested mainly detritus (39.06), euphausiids (30.90) and crustacean

Table 10. Index preponderance of *O. typus* in different depth zones.

Depth range (m)	0-100	100-200	200-300	300-400	400-500	700-800	Avg
Detritus	59.19	21.4	18.91	37.12	-	29.05	27.61
Chaetognaths	18.48	10.73	05.75	17.46	60.00	-	18.74
Crustacean remains	03.67	12.08	14.61	17.68	-	31.44	13.25
Fish remains	03.43	18.96	06.70	20.73	40.00	01.44	08.54
Shrimp remains	03.00	19.04	15.02	03.17	-	21.43	16.94
Euphausiids	01.21	05.40	33.35	00.38	-	15.45	09.3
Diatoms	06.81	12.07	04.59	02.6	-	01.19	04.54
Copepods	04.21	00.32	01.07	00.58	-	-	01.03
Foraminifera	-	-	-	00.28	-	-	00.05
Sample size	56	78	76	173	1	28	412

Table 11. Index of preponderance of food items of males and females *O. typus* in different depth zones

Depth (m) Sex/ Food items	0-100 m		100-200 m		200-300 m		300-400 m		400-500		700-800 m		Avg	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Detritus	83.25	35.12	16.28	26.52	28.60	9.22	36.40	37.83	-	-	39.06	19.04	33.93	25.55
Chaetognaths	06.81	30.15	19.71	1.75	03.54	7.96	27.9	7.02	60	-	-	-	19.66	9.38
Crustacean remains	02.39	04.94	15.25	8.9	19.64	9.58	12.33	23.03	-	-	27.17	35.72	12.8	16.43
Fish remains	02.36	04.5	23.98	13.94	08.57	4.84	18.92	22.54	-	-	02.87	-	09.45	9.16
Shrimp remains	-	06.00	-	38.08	-	30.05	02.3	4.04	40	-	-	42.86	07.05	24.21
Euphausiids	-	02.43	-	10.81	29.43	37.27	00.11	0.66	-	-	30.9	-	10.07	10.23
Diatoms	05.19	08.43	24.14	-	08.44	0.73	01.41	3.79	-	-	-	2.38	06.53	3.07
Copepods	-	08.43	00.64	-	01.78	0.35	00.63	0.53	-	-	-	-	00.51	1.86
Foraminifera	-	-	-	-	-	-	-	0.56	-	-	-	-	-	0.11
Samples size	37	19	18	60	36	40	81	92	1	-	25	3	198	214

remains (27.17). The composition of food from different depth zones is given in Table 11.

4. 4 FEEDING INTENSITY

4.4.1 Monthwise intensity of feeding

The monthwise feeding intensity of *O.typus* based on the fullness of stomach was studied. The maximum feeding intensity was observed in June (62.79%) followed by December (45.16%). During the other month they were found in poorly fed condition with percentage varying (April- 40.28%; May-37.23%; and October-30.3%) (Figure 65). Based on the entire period of the observation, actively fed shrimps formed only 38.59% (159 numbers) and the rest (253 numbers) being poorly feed (61.41%).

Actively fed males (87.5%) were observed in December. Females were found to be few, actively feeding with highest percentage of 62.79% in June (Table 12 &13). Males and females with appreciable feeding intensity were observed in May (46.15%) and April (43.01). If the total observation is taken into account, both sexes were found to be poorly fed during most of the times. (Males 63.64%; Females 59.35%).

4.4.2 Timewise intensity of feeding

Feeding intensity was found to be high during early morning hours of 04-08 hrs (53.25%), followed by the late evening hours of 16-20 hours (43.16%). It was lowest during 08-12 hours (20%) and 20-24 hours (20.15%) (Figure 66).

Both males and females showed similar trend of active feeding during 04-08 hrs (63.64%) and 16-20 hrs (48.82%) (Table 14 & 15).

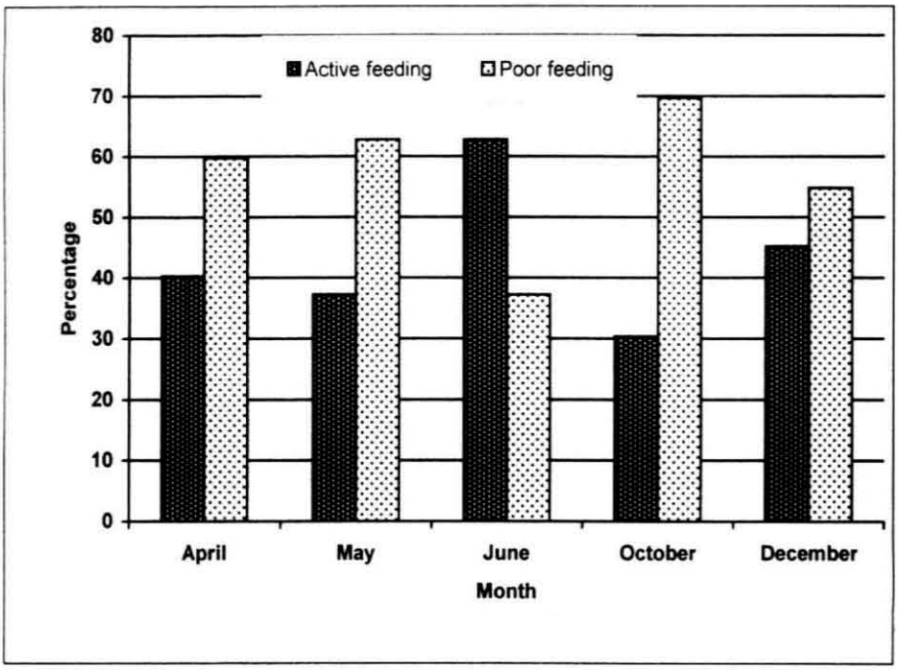

Figure 65. Feeding intensity of *O. typus* in relation to months

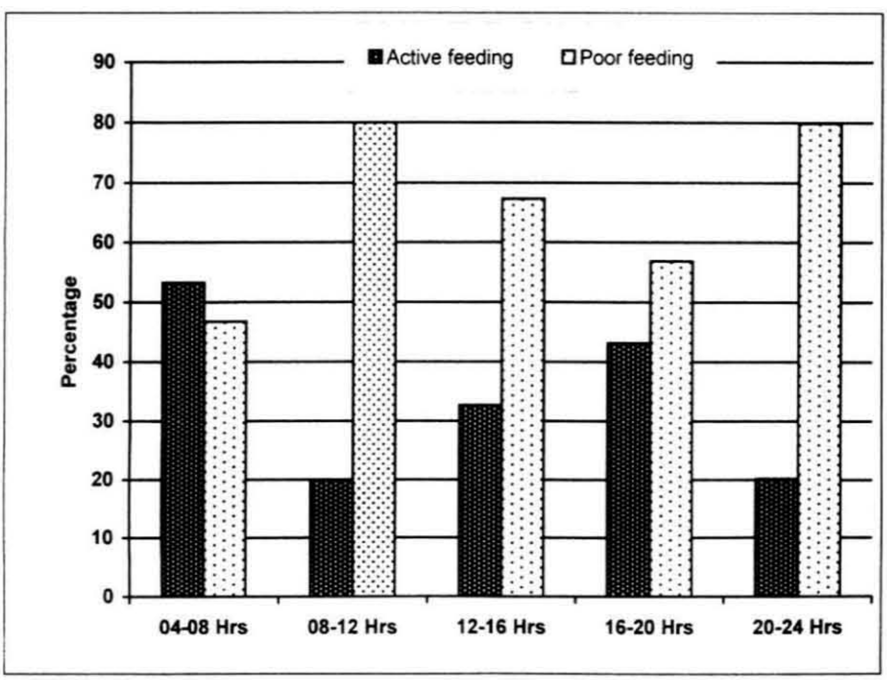

Figure 66. Feeding intensity of *O. typus* in relation to time

Table 12. Monthwise feeding intensity in males of *O.typus*

Degree of feeding	Empty	Trace	1/4 Full	1/2 Full	3/4 Full	Full	Actively fed	Poorly fed	Sample size
April									
No	31	25	17	22	6	17	45	73	118
%	26.27	21.19	14.41	18.64	5.08	14.41	38.14	61.86	
May									
No	10	1	10	6	5	7	18	21	39
%	25.64	2.56	25.64	15.38	12.82	17.95	46.15	53.85	
June									
No	-	-	-	-	-	-	-	-	-
%	-	-	-	-	-	-	-	-	
October									
No	6	8	4	3	1	3	7	18	25
%	24	32	16	12	4	12	28	72	
December									
No	8	4	2	1	-	1	14	2	16
%	50	25	12.5	6.25	-	6.25	87.5	12.5	
Total									
No	55	38	33	32	12	28	72	126	198
%	27.78	19.19	16..67	16.16	6.06	14.14	36.36	63.64	

Table 13. Monthwise feeding intensity in females of *O. typus*

Degree of feeding	Empty	Trace	1/4 Full	1/2 Full	3/4 Full	Full	Actively fed	Poorly fed	Sample size
April									
No	15	18	20	15	8	17	40	53	93
%	16.13	19.35	21.51	16.13	8.60	18.28	43.01	56.99	
May									
No	15	10	13	7	6	4	17	38	55
%	27.27	18.18	23.64	12.73	10.91	7.27	30.91	69.09	
June									
No	0	9	7	11	6	10	27	16	43
%	0	20.93	16.28	25.58	13.95	23.26	62.79	37.21	
October									
No	1	4	-	1	-	2	3	5	8
%	12.5	50	-	12.5	-	25	37.5	62.5	
December									
No	8	4	3	-	-	-	-	15	15
%	53.33	26.67	20	-	-	-	-	100	
Total									
No	39	45	43	34	20	33	87	127	214
%	18.23	21.03	20.09	15.89	9.34	15.42	40.65	59.35	

Table 14. Timewise feeding intensity in males of *O.typus*

Degree of feeding	Empty	Trace	1/4 Full	1/2 Full	3/4 Full	Full	Actively fed	Poorly fed	Sample size
00-04 hrs									
No	-	-	-	-	-	-	-	-	-
%	-	-	-	-	-	-	-	-	-
04-08 hrs									
No	1	-	3	1	2	4	7	4	11
%	9.09	-	27.27	9.09	18.18	36.36	63.64	36.36	
08-12 hrs									
No	-	-	-	-	-	-	-	-	-
%	-	-	-	-	-	-	-	-	-
12-16 hrs									
No	6	8	4	3	1	4	8	18	26
%	23.08	30.77	15.38	11.54	3.85	15.38	30.77	69.23	
16-20 hrs									
No	34	26	20	24	8	16	48	80	128
%	26.56	20.31	15.63	18.75	6.25	12.5	37.5	62.5	
20-24 hrs									
No	14	4	6	4	1	4	9	24	33
%	42.42	12.12	18.18	12.12	3.04	12.12	27.28	72.72	
Total									
No	55	38	33	32	12	28	72	126	198
%	25.29	15.8	19.12	12.87	7.83	19.09	39.79	60.21	

Table 15. Time wise feeding intensity in females of *O.typus*

Degree of feeding	Empty	Trace	1/4 Full	1/2 Full	3/4 Full	Full	Actively fed	Poorly fed	Sample size
00-04 hrs									
No	-	-	-	-	-	-	-	-	-
%	-	-	-	-	-	-	-	-	-
04-08 hrs									
No	1	3	-	1	-	2	3	4	7
%	14.28	42.86	-	14.29	-	28.57	42.86	57.14	
08-12 hrs									
No	-	4	-	1	-	-	1	4	5
%	-	80	-	20	-	-	20	80	-
12-16 hrs									
No	12	10	12	7	6	5	18	34	52
%	23.08	19.23	23.08	13.46	11.54	9.61	34.62	65.38	
16-20 hrs									
No	15	23	27	25	13	24	62	65	127
%	11.81	18.11	21.26	19.68	10.24	18.9	48.82	51.18	
20-24 hrs									
No	11	5	4	-	1	2	3	20	23
%	47.83	21.74	17.39	-	4.35	8.69	13.04	86.96	
Total									
No	39	45	43	34	20	33	87	127	214
%	19.40	36.39	12.35	13.48	5.23	13.15	31.87	68.13	

4.4.3 Depthwise intensity of feeding

The feeding intensity of *O.typus* in various depths showed that maximum active feeding was recorded in depths of 400-500 m (100%) followed by 200-300 m (57.64%), 700-800 m (47.34%) and 100-200 m (44.45%). In 0-100 m and 300-400 m depth ranges that were found to be poorly fed with 75.89% and 68.79% respectively (Figure 67).

In males, active feeding ones was maximum in the depths of 400-500 m (100%) followed by 200-300 m (52.78%) and 100-200 m (38.89%) . In female, the maximum percentage to active feeding was noticed in the depth range of 700-800 m (66.67%) followed by 200 –300 m (62.5%) and 300-400 m (30.43%) (Table 16 & 17).

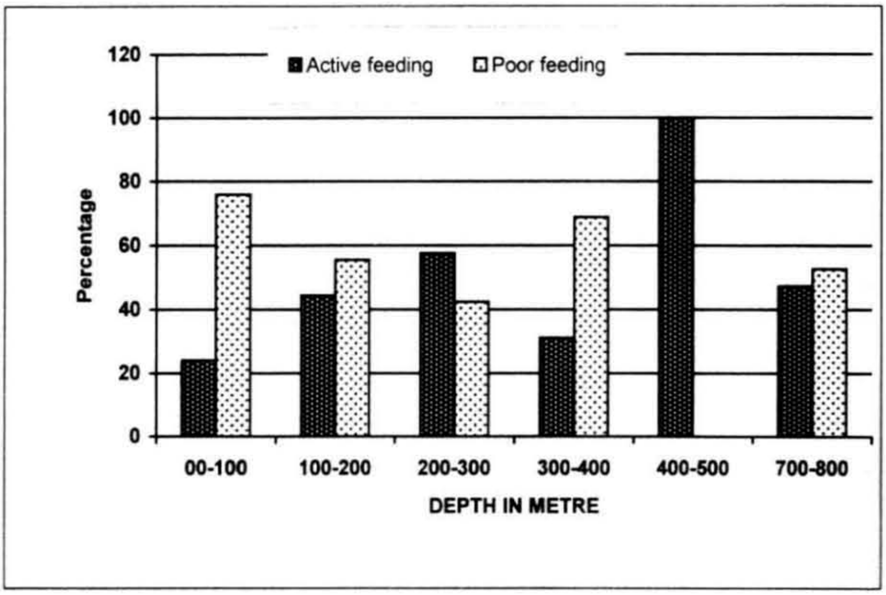

Figure 67. Feeding intensity in *O. typus* in relation to different depths

Table 16. Depthwise feeding intensity in males of *O.typus*

Degree of feeding	Empty	Trace	1/4 Full	1/2 Full	3/4 Full	Full	Actively fed	Poorly fed	Sample size
0-100 m									
No.	12	5	8	4	4	4	12	25	37
%	32.43	13.51	21.62	10.81	10.81	10.81	32.43	67.57	
100-200 m									
No.	7	-	4	4	1	2	7	11	18
%	38.89	-	22.22	22.22	5.56	11.11	38.89	61.11	
200-300 m									
No.	7	6-	4	8	3	8	19	17	
%	19.44	16.67	11.11	22.22	8.33	22.22	52.78	47.22	36
300-400 m									
No.	23	19	13	13	3	10	26	55	81
%	28.4	23.46	16.05	16.05	3.7	12.34	32.1	67.90	
400-500 m									
No.	-	-	-	-	-	1	1	-	1
%	-	-	-	-	-	100	100	-	
700-800 m									
No.	6	8	4	3	1	3	7	18	25
%	24	32	16	12	4	12	28	72	
Total									
No.	55	38	33	30	13	28	72	126	198
%	23.86	14.27	14.5	13.88	5.4	28.08	36.36	63.64	

Table 17. Depthwise feeding intensity in females of *O.typus*

Degree of freedom	Empty	Trace	1/4 Full	1/2 Full	3/4 Full	Full	Actively fed	Poorly fed	Sample size
0-100 m									
No.	8	4	4	1	1	1	3	16	19
%	42.11	21.05	21.05	5.26	5.26	5.26	15.79	84.21	
100-200 m									
No.	7	11	12	11	4	15	30	30	60
%	11.67	18.33	20	18.33	6.67	25	50	50	
200-300 m									
No.	3	5	7	10	5	10	25	15	40
%	7.5	12.5	17.5	25	12.5	25	62.5	37.5	
300-400 m									
No.	21	23	20	13	10	5	28	64	92
%	22.83	25	21.74	14.13	10.87	5.43	30.43	69.57	
400-500 m									
No.	-	-	-	-	-	-	-	-	-
%	-	-	-	-	-	-	-	-	
700-800									
No.	-	1	-	-	-	2	2	1	3
%	-	33.33	-	-	-	66.67	66.67	33.33	
Total									
No.	39	44	43	35	20	33	88	126	214
%	16.82	22.04	16.06	12.54	7.06	25.47	45.08	54.92	

4. 5 DISCUSSION

Oplophorus typus is an important and dominant component of the oceanic micro nekton and constitutes an important link between the zooplankton and higher trophic level carnivores in the pelagic ecosystem (200-1000 m) with much of the assemblage exhibiting vertical migration in to the epipelagic zones at night (0-200 m). They ascend the water column along with the vertically moving mesozooplankton during dark and descend downwards by morning. The concentration and migration of *O.typus* might be influenced by the availability of the prey organisms. The feeding activity was generally high in the surface layers and minimal at depths. Mainly euphausiids, decapods, fish eggs/larvae, copepods, chaetognaths, pteropods, heteropods, crustacean larvae, ostracods and mysids constitute the zooplankton biomass of the DSL and these planktonic components of the DSL showed marked variations between day and night.

Menon, (1990) stated that the major constituents of DSL are euphausiids, decapods, larval crustaceans, siphonophores, medusae, copepods, pteropods heteropods, amphipods, ostracods, prochordates, chaetognaths and larval, juvenile and adult fishes. The present findings suggest that *O.typus* feed selectively on detritus with an Index of 37.76 followed by crustacean remains (14.11), chaetognaths (12.30), shrimps remains (12.11), euphausiids (9.7), fish remains (8.53), diatoms (4.45), copepods (0.96) and foraminifera (0.08). Flock and Hopkins (1992) observed that Sergestids are zooplanktivores, with crustaceans as the predominant food. The important individual diet categories are copepods, ostracods, euphausiids, coelenterates, chaetognaths and olive coloured debris. According to Donaldson (1975) most species of *Sergestes* feed on the available organisms in their own surroundings. *Sergestes similes, S.lucens* and *Pasiphaea pacifica* inhabiting the lower most depth of 200 m at night, feed chiefly on herbivores, calanoids, copepod, and euphausiids (Omori 1974).

Detritus formed the major diet of *O.typus.* (37.76). However, variation was seen during different seasons. In December the feeding of *O. typus* was found to be higher

(74.16) when compared with the indices of October (27.47), May (18.94) and June (18.24). Detritus has been considered to be a lightly nutritive food, since the material has a considerable amount of associated bacterial biomass (Wiernicki, C 1984). Nandakumar and Damodaran (1998) included this 'decomposed plant and animal matter and their remains mixed with unidentified materials'. Flock and Hopkins (1992) stated that olive coloured debris as one of the food component of sergestides. According to Donaldson (1975) *S. joponicus* was mainly feeding on detritus. The present study shows that the detritus formed the most important food item of *O.typus*.

The crustacean remains formed the second dominant food item of *O. typus* (14.11). These processed materials appear to consist primarily of crustacean fragments and aggregations of fibrous and granular debris, which showed that the upper mesopelagic shrimps fed mainly on decomposing dead materials. As a constituent of its food, the crustacean remains were found to be in abundance in the stomach of *O. typus* during the months of October (27.71) and June (20.95).

Chaetognaths formed the third major food item (Index of 12.30) with maximum values in June (19.57). The present result confirms with that of Srinivasan (1996) who reported chaetognaths abundance (52.5) during June-September. Earlier, he (1990) reported that the density of the chaetognaths population was very rich along the west coast (Cochin and Mangalore) and plays a key role in the food chain. *O. typus* feeds on chaetognaths because of its relative abundance. Mathew (2000) stated that *Sagita enflata* formed 75% among chaetognaths in the eastern Arabian Sea.

Shrimp remains constituted (12.11) fourth important food item of *O. typus* and very little variation was observed during June and October. *O. typus* fed on euphausiids mainly during May (23.86) and October (19.51). The sixth dominant food items of *O. typus* are fish remains (8.53) and found to be feeding mainly in October (24.71) and June (20.95).

Diatoms formed a minor constituent of the food items during May. Omori (1974) observed that diatoms and dinoflagellates formed one of the constituent foods of *Oplophorus quadrispinosa*. Copepods formed as a food item of *O. typus* mostly in May (3.21) and foraminifera was present in the gut of *O. typus* in very small quantity during May.

During day and night studies on the differences in the food relationship of *O. typus* it was found that there were noticeable differences in the selectivity of food items. During daytime *O. typus* mainly preferred detritus (30.32,) and chaetognaths (18.90) and it preferred detritus (34.77) and euphausiids (15.51) during night. Males mainly fed on chaetognaths and fish remains whereas, females fed on detritus and crustacean remains. At night both males and females preferred detritus and euphausiids.

From the timewise studies it is seen that shrimp remains appeared as dominant food items of *O. typus* during early morning hours (04- 08). In the mid-day it preferred crustacean remains and detritus (8-16 hours) and late evening (16- 20 hours) it fed mainly on detritus. In the depthwise observations, detritus was the preferred food item in the depth of 0-100 m, 100-200 m and 300-400 m. In the depth range of 200 – 300 m it fed mainly on euphausiids. Chaetognaths were the main food item at 400-500 m depths.

Feeding intensity observations revealed that, actively fed shrimps constituted 38.59% (159 nos.) and the feeding intensity was higher in females of *O.typus* than the males. Day and night results show that no significant differences in the food preference of males and females.

CHAPTER 5

LENGTH-WEIGHT RELATIONSHIP OF *Oplophorus typus*

CHAPTER 5

LENGTH -WEIGHT RELATIONSHIP OF *OPLOPHORUS TYPUS*

5. 1 INTRODUCTION

The decapod crustaceans (mainly prawns and spiny lobsters) are of importance for marine fisheries in the Indian Ocean countries (Longhurst, 1970). Due to their value, the crustaceans are extensively studied in many countries. Information on length-weight relation of shrimps is needed in studies on growth and sexual maturity and for obtaining yield estimates by analytical models. Growth is manifested as an increase in size of the prawn and as such is best measured in terms of its volume or weight. But it is usually gauged from observation of its linear dominations, i.e. and total length. It has been mathematically proved that there is a fairly constant relationship between total length and weight of the individuals of the species. Therefore, when knowledge of the growth in volume or weight is required, it is usually calculated from length-weight relationship.

As prawns are exported as ' headless' variety, to find out, the total length and total weight from the tail weight alone, the relationship between total length and tail weight are needed. For comparison of data from different source the relationship existing between total length and carapace length is required. In view of the fluctuating nature of prawn fisheries and the importance of size composition in population studies, the relation between tail length and total length and total length and carapace length for males and females of *O.typus* was calculated. The relationship appears to be linear for the range of size examined. The prawn fisheries have assumed economic importance in view of their export potential.

The relationship between the tail length and total length and carapace length and total length for both sexes of the *O.typus* appears to be linear, for the range of size examined. This study was based on the samples of *O.typus* collected during October 1998 to May 2000 from IKMT collections from depth of 75 - 750 m along the west coast of India. Nevertheless, length and weight relationship is established only for few decapods inhabiting the western Indian Ocean (Longhurst, 1970).

The present account furnishes a detailed study of the length and weight relationship covering the entire length ranges as well as the other dimensional relationship of *O.typus*, an attempt was made for the first time for this species along this area.

5. 2 MATERIALS AND METHODS

Samples of O. *typus* collected from the IKMT catch in the west coast of India during October 1998 - May 2000 were utilized for the studies on length-weight relationship. The details on total length, carapace length, total weight, tail weight, were collected. Sexwise measurements of total length (tip of telson to post orbital margin of carapace), tail length (tip of the telson to margin of first abdominal segment), and carapace length (dorsal portion of the postorbital margin to mid posterodorsal margin of the carapace) were taken to the nearest millimetre using vernier calipers.

Data collected for the two years period (October 1998- May 2000) were pooled to represent all available size groups in the pelagic fishery. Weight may be considered as a function of length. Therefore, a more satisfactory formula for the expression of the relationship is -

$$W = aL^b$$

where W= Weight, L= Length

'a' and 'b' are constants and expressed logarithmatically as log W= a+b log L

The data for total length - total weight and total length–tail weights were plotted and an exponential relationship was observed between these parameters. Logarithmic transformation was adopted for these relationship, as log W + a+b log L. The relationship between total weight and tail weight as well as the total length and carapace length were found to be linear and they were calculated by the method of least squaress on the basis of individual measurements. To learn whether the regression of different parameters are significantly different between males and females, analysis of covariance (Snedecor and Cocharan, 1968) was employed.

The estimates of regression co-efficient (both males and females) were tested for finding the significance of variation from the expected value of 3 by employing the 't' test using the formula

5.3 RESULTS

5.3.1 TOTAL LENGTH-TOTAL WEIGHT RELATIONSHIP

Males

A total of 200 males ranging in total length from 2 to 4.8 cm and total weight from 0.1 to 1.93 g was measured to study the total length – total weight relationship of *O. typus*.

The total length and total weight scatter diagram (Figure 68) gave the exponential form of the equation as: $W= 0.000119522\ L^{2.90109}$

The Log-log transformation gave the equation as: $\text{Log}W= -3.92255+2.90109\text{Log}\ L$

The correlation coefficient value estimate was: $r = 0.925715$

Females

A total of 213 females ranging in total length from 2 to 4.6 cm and ranging in total weight from 0.12 to 1.77 g was measured to study the total length and total weight relationship of *O.typus.*

The total length and total weight scatter diagram (Figure 69) gave the exponential form of the equation as: $W=0.00013863L^{2.83368}$

The Log-log transformation gave the equation as: $\text{Log}W= -3.85812+2.83368\ \text{Log}\ L$

The correlation coefficient value estimate was: $r = 0.945955$

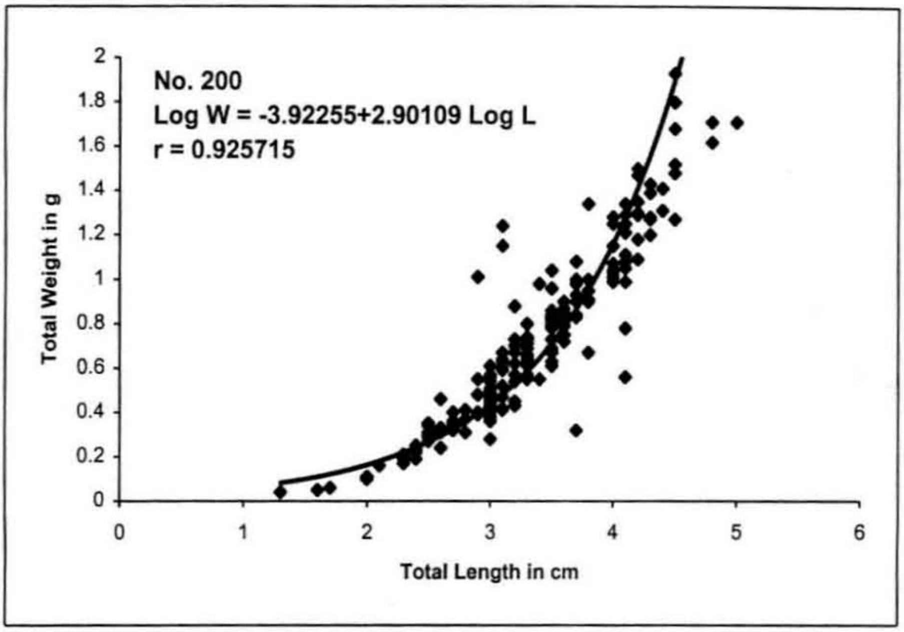

Figure 68. Total length - total weight relationship - Male

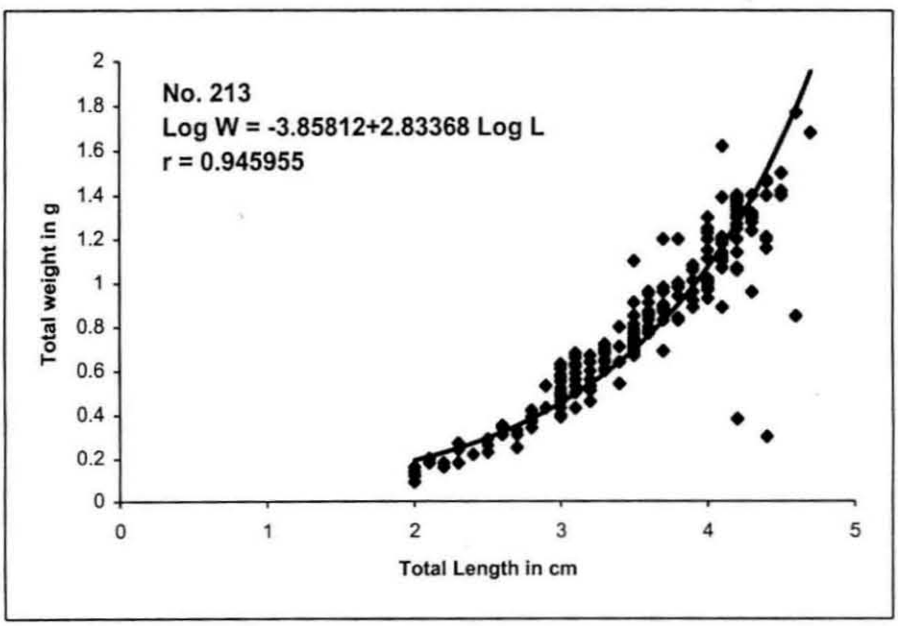

Figure 69. Total length - total weight relationship - Female

Pooled

The length - weight relationship of male and female was tested for significance by ANACOA (Snedecor and Cochron, 1968) and results are given Table 18. As there was no significant difference in the slopes and elevations of the two sexes, the data was pooled to arrive at a common formula for the species.

The exponential form of the equation as : $W= 0.000131416L^{2.85937}$

The Log-log transformation gave the equation as : Log W= -3.88135+ 2.85937 Log

The correlation coefficient value estimate was : r =0.936757

The significance of the variation in the estimate of 'b' value from the cubic relation was tested by the 't' test as given by the formula : $t = \frac{b - \beta}{S_b}$, 't' values of both males and females are given below.

$$t = \frac{2.85937 - 3.0000}{0.02497} = -5.6319$$

The 't' value was found to be non-significant hence, the cubical relationship (3) holds good for length-weight relationship.

Table 18. Comparison of total length-total weight relationship of *O. typus*

ANOVA TABLE

SOURCE	DF	SS-X	SP	SS-Y	b	DF	SS	MS	F
Male	200	6.4361	18.6718	63.2110	2.901	199	9.042	0.04544	
Female	213	8.2776	23.4560	74.2786	2.834	212	7.812	0.03685	
Total						411	16.854	0.04101	
Pld w	413	14.7137	42.1278	137.4896	2.863	412	16.871	0.04095	
Different between slopes						1	0.016	0.01645	0.40
Between	1	0.0972	0.2222	0.5077					
W + B	414	14.8109	42.3500	137.9973	2.859	413	16.903	0.04093	
Different between corrected means						1	0.032	0.03226	0.79

SOURCE	MEAN-X	MEAN –Y	a	b	r
Male	1.205	-0.427	-3.92255	2.90109	0.925715
Female	1.236	-0.357	-3.85812	2.83368	0.945955
POOLED	1.221	-0.390	-3.88135	2.85937	0.936757

5. 3. 2 TOTAL LENGTH -TAIL WEIGHT RELATIONSHIP

Males

A total of 200 males ranging in total length from 2 to 4.8 cm and tail weight from 0.07 to 0.62 g was measured to study the total length –total weight relationship of *O. typus*.

The total length and total weight scatter diagram (Figure 70) gave the exponential form of the equation as : $W= 0.0000151\, L^{2.85249}$

The Log-log transformation gave the equation as : $\mathrm{Log}W= -4.81889 + 2.85249\ \mathrm{Log}\ L$

The correlation coefficient value estimate was : $r = 0.961114$

Females

A total of 213 females ranging in total length from 2 to 4.6 cm and ranging in tail weight from 0.12 to 1.77 g was measured to study the total length and total weight relationship of *O.typus*.

The total length and tail weight scatter diagram (Figure 71) gave the exponential form of the equation as: $W=0.0000098\, L^{2.99487}$

The Log-log transformation gave the equation as : $\mathrm{Log}W= -5.00388 + 2.99487\ \mathrm{Log}\ L$

The correlation coefficient value estimate was : $r = 0.939157$

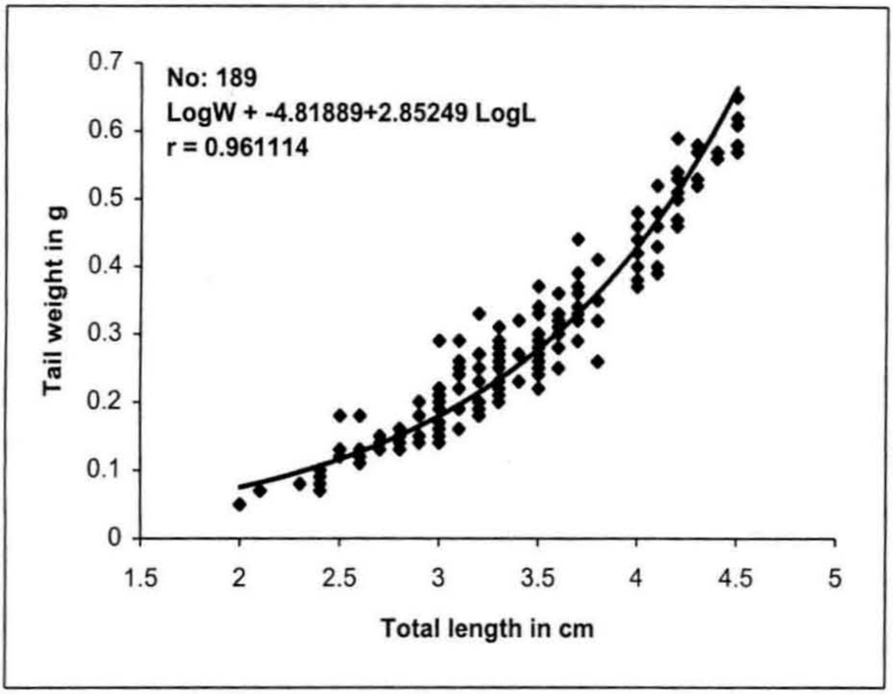

Figure 70. Total length -tail weight relationship - Male

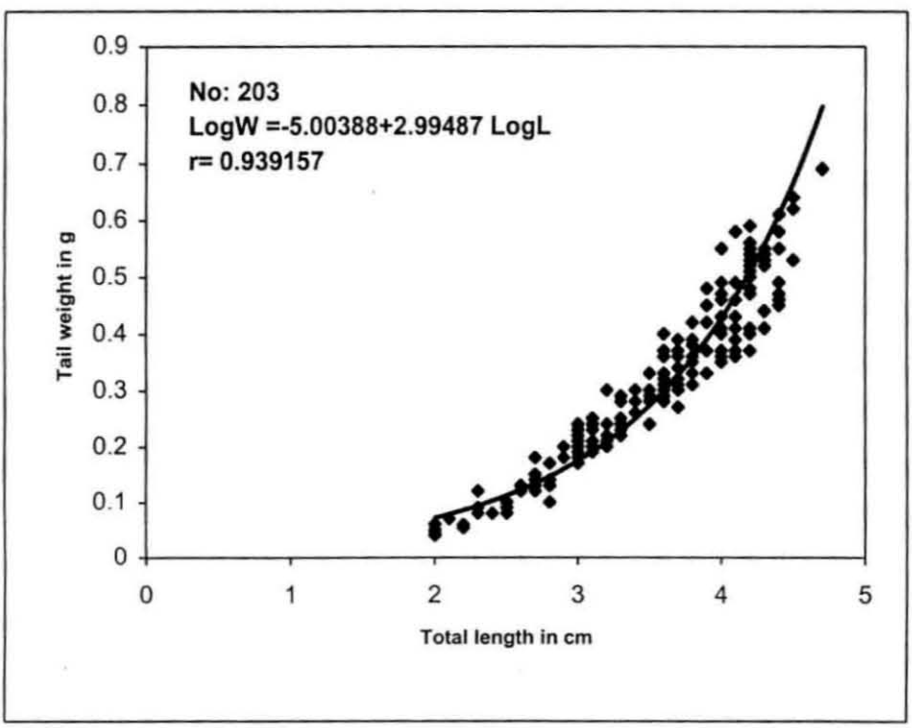

Figure 71. Total length-tail weight relationship - Female

Table 19. Comparison of total length-tail weight relationship of *O. typus*

ANOVA TABLE

SOURCE	DF	SS-X	SP	SS-Y	b	DF	SS	MS	F
Male	189	5.9336	16.9255	52.2658	2.852	188	3.986	0.02120	
Female	203	7.8380	23.4739	79.7050	2.995	202	9.404	0.04655	
Total						390	13.390	0.03433	
Pld w	392	13.7716	40.3994	131.9708	2.934	391	13.458	0.03442	
Different between slopes						1	0.068	0.06845	1.99
Between	1	0.0656	0.1626	0.4030					
W + B	393	13.8372	40.5620	132.3738	2.931	392	13.472	0.03437	
Different between corrected means						1	0.013	0.01346	0.39

SOURCE	MEAN-X	MEAN –Y	a	b	r
Male	1.206	-1.379	-4.81889	2.85249	0.961114
Female	1.232	-1.315	-5.00388	2.99487	0.939157
POOLED	1.219	-1.346	-4.92005	2.93137	0.947750

Pooled

The length and tail weight relationship of male and female was tested for significance by ANACOA (Snedecor and Cochron, 1968) and results are given in Table 19. As there was no significant difference in the slopes and elevations of the two sexes, the data was pooled to arrive at a common formula for the species.

The exponential form of the equation was : $W=0.00001221\ L^{2.93137}$

The Log-log transformation gave the equation as : $\text{Log}W = -\ 4.92005 + 2.93137\ \text{Log}\ L$

The correlation coefficient value estimate was : $r = 0.947750$

The significance of the variation in the estimate of 'b' value from the cubic relation was tested by the 't' test as given by the formula : $t = \dfrac{b - \beta}{S_b}$, 't' values of both males and females are given below.

$$t = \frac{2.93137 - 3.0000}{0.0314} = -2.1856$$

The 't' value was found to be non-significant hence, the cubical relationship (3) holds good for length- tail weight relationship.

5. 3. 3 TOTAL WEIGHT - TAIL WEIGHT RELATIONSHIP

Males

A total of 200 males ranging in total weight from 0.1 to 1.93 gram and tail weight from 0.07 to 0.93 gram were measured to study the total weight and tail weight relationship. The total weight and tail weight scatter diagram as plotted (Figure 72).

Females

A total of 213 females ranging in total weight form 0.12 to 1.77 gram and tail weight from 0.04 to 0.67 gram were measured to study the total weight and tail weight relationship. The total weight –tail weight scatter diagram as plotted (Figure 73).

The analysis of covariance showed that there was no significance between the regression coefficient of male and female Table 20.

Hence, the single equation calculated for the total weight and tail weight in both sexes is as follows. Total weight (X) and Tail weight (Y)

$$Y=0.02270+0.36316\ X\ (r = 0.919570)$$

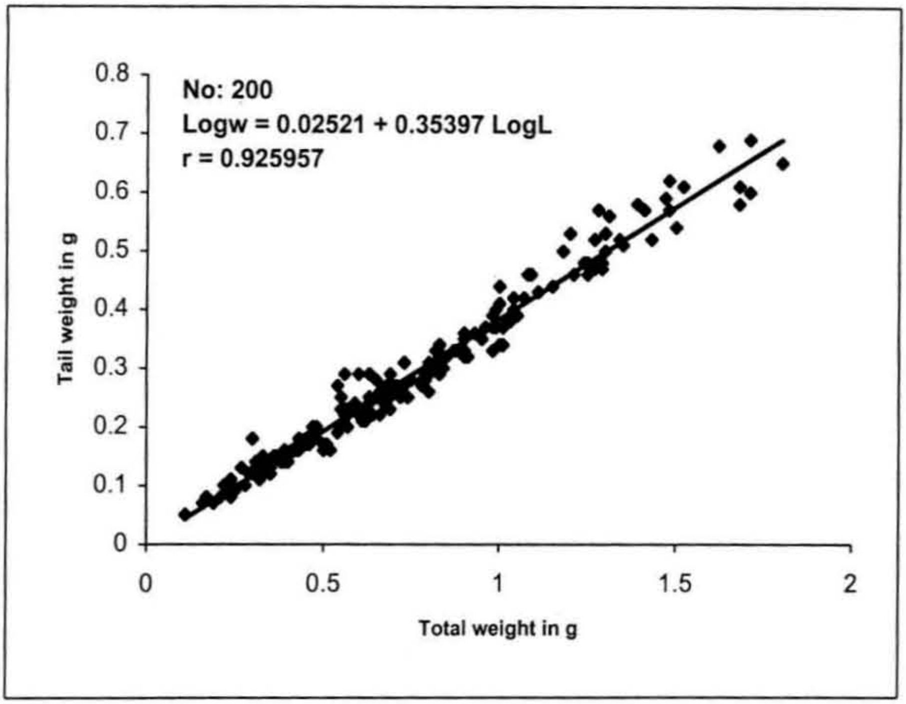

Figure 72. Total weight - tail weight relationship-Male

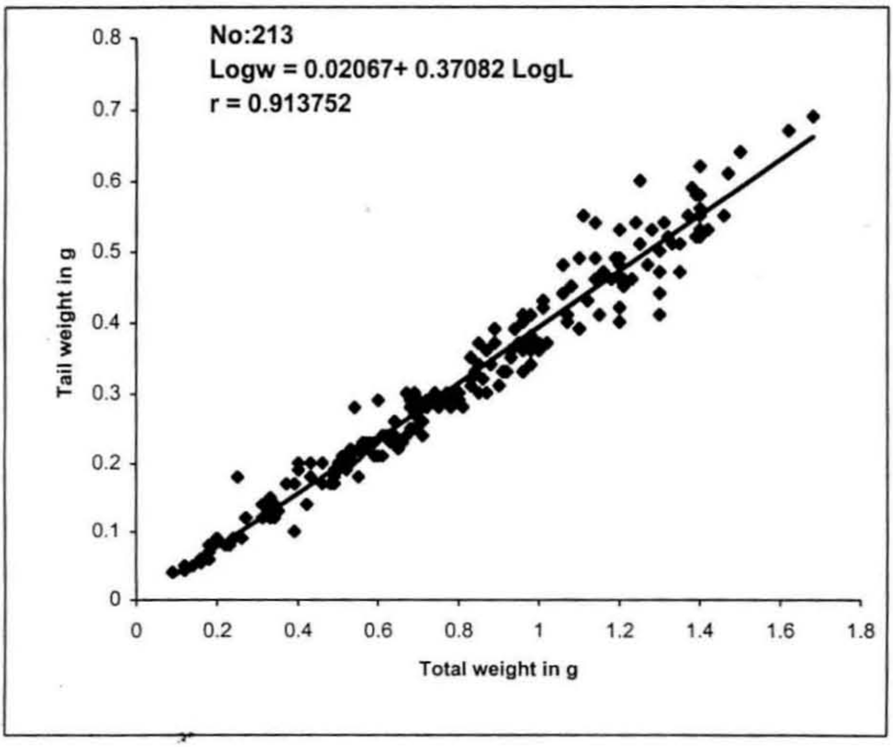

Figure 73. Total weight - tail weight relationship-Female

Table 20. Comparison of total weight-tail weight relationship of *O. typus*

ANOVA TABLE

SOURCE	DF	SS-X	SP	SS-Y	b	DF	SS	MS	F
Male	200	30.5709	10.8211	4.4674	0.354	199	0.637	0.00320	
Female	213	30.4177	11.2795	5.0095	0.371	212	0.827	0.00390	
Total						411	1.464	0.00356	
Pld w	413	60.9885	22.1006	9.4769	0.362	412	1.468	0.00356	
Different between slopes						1	0.004	0.00433	1.22
Between	1	0.3036	0.1583	0.0826					
W + B	414	61.2922	22.2589	9.5595	0.363	413	1.476	0.00357	
Different between corrected means						1	0.008	0.00765	2.15

SOURCE	MEAN-X	MEAN –Y	a	b	r
Male	0.754	0.292	0.02521	0.35397	0.925957
Female	0.808	0.320	0.02067	0.37082	0.913752
POOLED	0.782	0.307	0.02270	0.36316	0.919570

5. 3. 4 TOTAL LENGTH - CARAPACE LENGTH RELATIONSHIP

Males

A total of 200 males ranging in total length from 2 to 4.8 cm and carapace length 0.7 to 1.5 cm was measured to study the total length and carapace length relationship. The total length and carapace length scatter diagram was plotted (Figure 74).

Females

A total of 213 females ranging in total length 2 to 4.6 cm and carapace length 0.7 to 1.5 cm was measured to study the total length and carapace length relationship. The total length and carapace length scatter diagram was plotted (Figure 75).

The analysis of covariance showed that there was no significant difference between the regression coefficient of male and female (Table 21). Hence, the single equation calculated for the total length (TL) and carapace length (CL) in both sexes is as follows:

$CL = 0.11689 + 0.28415\ TL$ ($r = 0.880071$).

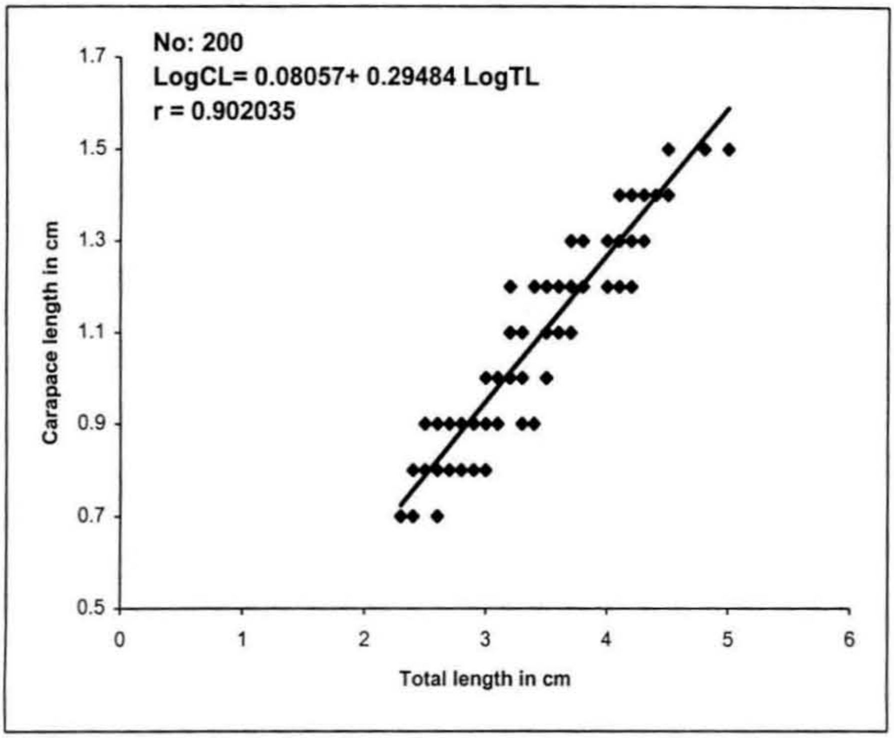

Figure 74. Total length-carapace length relationship - Male

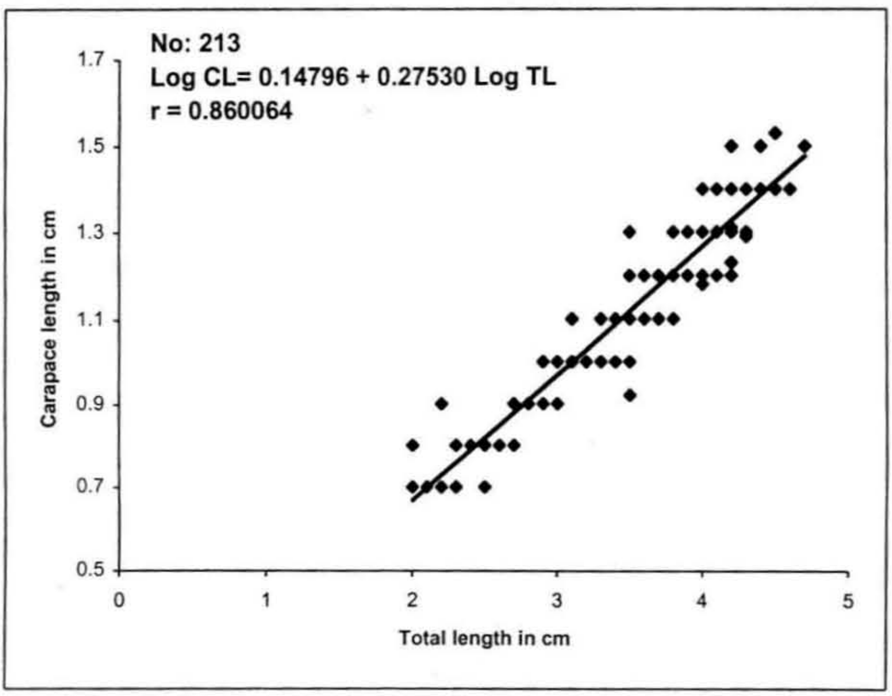

Figure 75.Total length-carapace length relationship- Female

Table 21. Comparison of total length-carapace length relationship of *O. typus*

ANOVA TABLE

SOURCE	DF	SS-X	SP	SS-Y	b	DF	SS	MS	F
Male	200	71.7001	21.1402	7.6604	0.295	199	1.427	0.00717	
Female	213	86.8062	23.8976	8.8940	0.275	212	2.315	0.01092	
Total						411	3.742	0.00911	
Pld w	413	158.5063	45.0378	16.5544	0.284	412	3.757	0.00912	
Different between slopes 1.65						1	0.015	0.01500	
Between	1	1.3507	0.3853	0.1099					
W + B	414	159.8570	45.4231	16.6643	0.284	413	3.757	0.00910	
Different between corrected means 0.00						1	0.000	0.000000	

SOURCE	MEAN-X	MEAN –Y	a	b	r
Male	3.390	1.080	0.08057	0.29484	0.902035
Female	3.504	1.113	0.14796	0.27530	0.860064
POOLED	3.449	1.097	0.11689	0.28415	0.880071

5.4 DISCUSSION

The study of length–weight relationship in *O.typus* shows an exponential relationship. Initially the relationship for males and females was found out separately, which was tested for significance by using analysis of covariance (ANACOA) (Snedecor and Cochran, 1968). As there was non-significant difference between the two sexes, the data was pooled to arrive at a common formula for the species as $W = 0.000131416 \, L^{2.85937}$. The significance of variation in the estimate of 'b' value from the cubic relation was tested by the 't' test and it was observed that the cubical relationship holds good for length-weight relationship.

As there was no information on the length-weight relationship of other pelagic shrimps of deepwater regions of India, some of the works done on the penaeid prawns in the shallow waters are discussed here. Murthy and Ramaseshaiah (1996) studied the relationship between length and weight for *Metapeneaus dobsoni* from the Vishakapatnam coast by analysis of covariance and they did not find any significant difference between both sexes. Achuthenkutty and Parulkar (1986) compared the regression coefficient of males and females of both juveniles and adults of *Penaeus merguiensis* from Goa waters by analysis of covariance and they did not find significant difference between sexes in juveniles as well as in adults. The length-weight relationship of some penaeid prawns showed significant difference between males and females and separate equation was calculated for the each sex. Such observation was made by Rao (1988), and Nandakumar (1998) in *M.monocers* and Ramaseshaiah and Murthy (1997) in *M.barbora*.

The relationship between total length-tail weight is not significantly different for the two sexes. Therefore, a common equation has been calculated as $W = 0.00001221 \, L^{2.93137}$. The significance of variation in the estimate of 'b' value from the cubic relation was tested by the 't' test and it was observed that the cubical relationship holds good for length-tail weight relationship also. In their study on total length-tail weight relationship in *M.dobsoni* from Vishakapatnam coastal waters Murthy and Ramaseshaiah (1996) did not observe any significant difference between sexes and gave one common formula for both sexes combined.

In total weight-tail weight relationship of *O.typus* there was no significant difference between sexes, and hence the data was pooled to arrive at a common formula for the species as W = 0.02270 + 0.36316 X (r = 0.919570). Similar observation was made by Murthy and Ramaseshaiah (1996) in *M. dobsoni* of the Vishapatanam coast and Rao (1988) in *M.monoceros* of the Kakinada coast.

In the present study, the relationship between the total length-carapace length is not significantly different for males and females and a common equation was derived as CL = 0.011689 + 0.28415 TL (r = 0.880071). Ramamurty and Manickaraja (1978) did not observe any difference between juveniles and adults in the carapace length and total length relationship in *Penaeus stylifera, Metapenaeus dobsoni* and *M.affinis*. Murthy and Ramaseshaiah (1996) studying on the total length - carapace length relationship of *M. dobsoni,* gave separate equation for each sex, as there were significant differences between sexes.

SUMMARY

The present investigation is based on the pelagic shrimps of the DSL collected during the cruises **FORV *SAGAR SAMPADA*** during May 1998 - December 2000, from the west coast of India. The study is aimed at understanding the role of pelagic shrimps in the DSL ecosystem and to study the exploitable biomass of pelagic shrimp of the Indian EEZ.

The thesis embodies the results of detailed taxonomic works on the pelagic shrimps, their distribution, abundance, biomass, food and feeding habits, and length-weight relationship of the most commonly occurring species namely, *Oplophorus typus*.

1. A detailed estimation on the spatial distribution and abundance of the pelagic shrimps and contiguous waters up to 21^0N has been attempted based on the 123 IKMT samples.

2. From the IKMT collections about 11 families, 19 genera and 29 species of pelagic shrimps were identified. These belong to Order Decapoda, and Infra orders Penaeidea, Caridea and Stenopodea. The families were Penaeidae, Benthesicymidae, Solenoceridae, Sergestidae, Luciferidae, Oplophoridae, Nematocarcinidae, Pasiphaeidae, Pandalidae, Thalassocarididae, and Stenopodidae.

3. The pelagic shrimps were predominantly constituted by 19 genera, which include, *Pelagopenaeus, Funchalia, Gennadas, Solenocera, Hymenopenaeus, Sergestes, Sergia, Acetes, Lucifer, Oplophorus, Acanthephyra, Meningodora, Notostomus, Nematocarcinus, Leptochela, Psathyocaris, Plesionika, Thalassocaris, and Stenopus.*

4. The 29 species of pelagic shrimps recorded from the DSL ecosystem of the west coast of India were *Pelagopenaeus balboae*, *Funchalia danae*, *Gennadas praecos*,

G. sordidus, G. scutatus, G. parvus, Solenocera hextii, Hymenopenaeus aequalis, Sergestes seminudus, S. semissis, S. orientalis, Sergia inous, Acetes japonicus, Lucifer typus, L. penicillifer, L. hanseni, L.orientalis, Oplophorus typus, Acanthephyra sanguinea, Meningodora sp, *Notostomus* sp, *Nematocarcinus tenuirostris, Leptochela (Leptochela) aculeocaudata, Leptochela (Leptochela) robusta, Psathyocaris* sp, *Plesionika martia, P.alcocki, Thalassocaris carinata and Stenupus* sp.

5. The pelagic shrimps formed an integral part of the DSL which were recorded both from shelf, slope and deep waters with depths above 300 m.

6. The pelagic shrimps were collected from surface down to about 750 m (the lower limit of IKMT coverage) over the entire west coast.

7. The estimated pelagic shrimp biomass (nos./1000m^3) varied from an average of 0.04 to 106.4 nos./1000m^3/haul. The maximum biomass recorded was at 18-74 degree squares (106.4 nos./1000m^3/haul) off Vizhinjam.

8. The pelagic shrimp catches were more during night (57%) than day (46%). During night, they were most dominant at 10–73 degree squares (112.5 nos./1000m^3).

9. The estimations of vertical distributions of pelagic shrimps showed that they were abundant at depth ranges of 50-200 m (77.22 nos./1000m^3). They were concentrated more in the upper strata (0-200 m) of the ocean.

10. The horizontal distributional analysis showed that they were more dense (1353 nos./1000m^3) in the deeper waters (1000-3000 m). Good catches were obtained from waters above 1000-3000 m during night (1219 nos./1000m^3).

11. Maximum density of family Pasiphaeidae was recorded at 10-73 degree squares (178 nos./1000 m^3) while that of family Thalassocaridae was observed at 08-74 degree squares (153 nos./ 1000 m^3), family Sergestidae at 06-76 degree squares (24 nos.1000 m^3), and family Oplophoridae at 8-72 degree squares (5.4 nos. 1000 m^3).

12. The biomass estimations were based on the ' Swept area method'.

13. The vertical distributional studies revealed that the maximum biomass was reported from above 300 m (54.93%) depth range. The horizontal distributional analysis showed that the maximum biomass was (27%) obtained from the shelf break region (2500-35000 m).

14. Rich concentrations of pelagic shrimps biomas (48.53%) were recorded during pre-monsoon season.

15. High biomass values were found at 06° latitude (5057t).

16. Food and feeding habits of *Oplophorus typus* have been studied based on stomach content analysis of 412 specimens. The major food items identified were detritus, chaetognaths, crustacean remains, fish remains, shrimp remains, euphausiids, diatom, copepods and foraminifera.

17. *O. typus* preferred mainly detritus (Index, 37.76), crustacean remains (Index, 14.11) and chaetognaths (Index, 12.30).

18. *O. typus* preferred detritus both during day (Index, 30.32) and night (Index 34.77), while during night euphausiids (Index 15.51) also formed a preferred component in their diet.

19. *O. typus* feeds mainly during early morning (04. 00-08.00) hours (Index 40.14), and these were found to occur at depths from surface down to 100 m during their active feeding time.

20. From the observation feeding intensity, the maximum feeding intensity was observed in the month of June (62.74%) and 100% actively fed fishes were obtained from depth ranges of 400-500 m.

21. In the length-weight relationship analysis of *O. typus*, both sexes were tested for significance by ANACOA and it was found that there was no significant difference in the slopes and elevations of the two sexes. The data was then pooled to arrive at a common formula for the species.

$$W = 0.000131416\ L^{2.85937}$$

The significance of variation in the estimate of 'b' value from the cubic relationship was tested using 't' test and found to be non-significant (-5.6319) and hence the cubic relationship (3) holds good for the length–weight relationship of the species.

22. The total length – tail weight relationship of *O. typus*, the both sexes were tested for significant by ANACOA and results showed that there was no significant difference in the slopes and elevations of the two sexes. The data was pooled to arrive at a common formula for the species.

$$W = 0.00001221\ L^{2.93137}$$

The significance of the variation in the estimate of 'b' value from the cubic relationship was tested using 't' test and found to be non-significant (-2.1856) and hence the cubic relationship (3) holds good for length –weight relationship.

23. The total weight – tail weight relationship for both sexes of the species establised by a single equation

$Y = 0.02270 + 0.36316\ X$ ($r = 0.919570$), where X = total weight and Y = tail weight.

24. The total length (TL) - carapace length (CL) relationship for the sexes of the species is also establised by a single equation.

$CL = 0.11689 + 0.28415\ TL$ ($r = 0.880071$)

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